WATER & SEWAGE WORKS

REFERENCE NUMBER

SEPTEMBER 15
1958

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For the 25th time
Water & Sewage Works is
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This 1958 Reference Number
is issued with the hope of the
publisher and the editor that it will
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This Reference Number,
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the benefit of new subscribers, this issue contains some basic material
charts, and data, used in previous issues.

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the Reference Number without extra charge.

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INTRODUCTION

Water and Sewage Works Practices

by GEORGE E. SYMONS, Ph.D.
Editor, Water & Sewage Works

MODERN development of both water and sewage treatment began about 1850 and progressed rapidly only after the understanding of the germ theory of disease and the role of water as a disease carrier. Although treatment of water and sewage developed somewhat independently, the two are so related as to be one field of study.

The oneness of water and sewage treatment exists for several reasons: (1) Both deal with important phases of public health. (2) Both deal with the same liquid, subject to the same hydraulic laws. (3) Both employ certain fundamental physical and chemical processes of treatment. (4) Both are concerned with the removal of undesirable matter from the liquid. (5) Both are community problems and in the realm of public service. (6) Both, being municipal functions, are frequently subject to the same management. (7) Sewage is the used water supply of a community.

Where an individual is interested in only water, he will find it not amiss to be acquainted with sewage treatment and vice versa. This introduction to the whole field is intended to set the scene for a basic appreciation of the technical articles and discussions which appear in the Reference and Data Edition of WATER & SEWAGE WORKS, as well as other publications.

Big Business—Broad Field

Water supply is the largest tonnage business in the world and sewage treatment probably is next in size as an industry. It is not size alone but also complexity of operations in both water and sewage works which establishes a need for management and supervision. Among the problems of management, with which a superintendent, engineer, or operator must contend are financing, rate structures, office operations, public relations and policies, legal problems, and safety.

In addition to a knowledge of management, operators or supervisors of water and sewage plants need to know some fundamentals of mathematics, hydraulics, design, construction, chemistry, biology, and bacteriology. No other field of endeavor requires a working knowledge of so many different technical and scientific fields.

Functional Operations

There are certain operations which are basically functional to both water and sewage works operations. These include pumping, flow measurement, instrumentation and control, chemical handling and feeding, coagulation and sedimentation, corrosion, laboratory control and maintenance.

Pumping is a most important operation common to both water and sewage handling. The type of pump, its capacity and characteristics, suction lift, discharge pressure, power required, controls, etc. depend on the service to which a pump is to be put.

Pumps for transferring water from a surface supply to a purification plant nearby, usually operate at a low discharge pressure and are known as "low service pumps." Pumps which discharge to distribution systems at relatively high pressures are known as "high service pumps." Today, electrically driven centrifugal pumps are used almost exclusively.

Sewage generally flows by gravity to point of discharge. In some cases where this is not possible, pumps are used to elevate the sewage as high as necessary to allow for ultimate disposal by gravity flow. Pumps are used at sewage works for pumping both sewage and sludge and at lift stations on sewer systems. Sewage pumps differ from water pumps in that they usually have low discharge pressures, and construction is such as to permit passage of relatively large objects.

Flow measurement and instrumentation are essential functions in both water and sewage works operations. In water works, one of the most important factors is a knowledge and record of the amount of water pumped or treated. Flow measuring devices, through instruments, also indicate the rate in gal. per min. or total the flow over the period of operation, or give an inked record of the rate of flow. These measuring devices also can be used to control, operate, or pace other equipment such as chemical feeders.

For water works, instruments are available to indicate or record level changes in reservoirs, pressure changes in distribution systems, loss of head in filters, and other phases of operation. Controls are available for rate of flow in filters, rate of flow in distribution systems, pump operation, chemical feeder operation and filter washing and even pump operation at distant well fields or at booster stations.

In a sewage plant, flow measurement of both sewage and sludge is highly desirable. One cannot operate a sewage works properly without a knowledge of the volumes being handled and treated. For the most parts both the metering devices and the instruments are the same as those used in water plants with slight modifications.

Corrosion Control is one plaguing problem in water treatment is the control of corrosion in distribution systems. Even small amounts of carbon dioxide or other substances which will lower the pH below neutral, will be sufficient to cause corrosion if there is not sufficient amount of buffering alkalinity present. Electrochemical action, involving oxygen as a hydrogen acceptor is a common cause of corrosion, as is galvanic action between two points of dissimilar metal content in a pipe. Pitting and tuberculation are two undesirable results since both reduce the carrying capacity of the pipe, red water also is an undesirable result.

Laboratory Control: No water works should be without some laboratory facilities. The extent of water treatment and size of the plant usually dictates the size of the laboratory, the frequency of testing, and the number and complexity of the tests to be made.

Maintenance is a term applied to keeping equipment in good operating condition and repairing breakdowns. No properly run water works should be operated without a preventive maintenance program, with regular lubrication, inspection of movable mechanisms, replacement of items subject to wear, painting, main cleaning, and regular checks of valves, and service meters. Preventive maintenance can avoid costly shutdowns.

WATER WORKS PRACTICE

The study of water supply begins with the hydrologic cycle. This is an unending natural phenomenon. Under the influence of the sun's heat, water rises, salt free, from the ocean reservoirs, is borne by the winds, and is precipitated onto the land from which it returns to the sea in various ways.

Source of Supply

Some water percolates into the earth. Most of this water passes again to the atmosphere by the process of transpiration through the foliage of vegetation. That which collects in aquifers below the surface of the ground is known as "ground water." Most of the precipitated water runs off the earth's surface and collects in streams, rivers, ponds, and lakes and is known as "surface water."

Both ground water and surface waters are used as a source of supply. Underground supplies may be shallow wells, infiltration galleries, or deep wells. Surface supplies may be rivers, impounded reservoirs, or lakes.

Distribution

The distribution system is a network of pipes with appurtenances for transporting water from the source of supply or purification plant to the customer's tap. The distribution system consists of transmission mains of large size, arterial mains of intermediate size, and minor distributors of 4 to 12 inch size, plus valves, hydrants and service connections. Pressure may be supplied by pumps, or by pumps and distributing reservoirs, or in gravity systems by reservoir alone.

The design, capacity, and layout of a distribution system with and without storage must consider many factors: Domestic needs, fire flow needs, ground level elevations in the community, pressure requirements, future requirements and growth factors of the community. Operation of a distribution system involves: Laying of mains, maintenance of flow and pressure, loss of carrying capacity, tuberculation, corrosion, main cleaning, maintenance of valves and hydrants, pipe lining, service tapping, service and meter installation, and meter reading.

Treatment

If water as obtained from natural sources is not suitable for domestic consumption, it must receive treatment to make it acceptable. Most common treatment of surface waters is for the removal of suspended matter (turbidity) and bacteria. If the water has other undesirable characteristics such as color, tastes and odors or is hard or corrosive, treatment processes may include some special operations. Well waters are usually clear, cool, and free of tastes, odors, and bacteria and require little treatment. Occasionally well waters may be too hard for domestic and industrial use or may be corrosive or contain undesirable amounts of iron, manganese or hydrogen sulfide. These constituents can and should be removed.

The type and extent of any treatment of any water supply depends on: The use to which the water is to be put, and the kind and character of the impurities. From the standpoint of public health, the most important treatment is the removal of bacteria, but the aethestic quality of the water is almost as important to the consumer. Industrial processes may require even greater purification than domestic supplies.

Coagulation and Sedimentation

Suspended matter or turbidity removal is accomplished by chemical coagulation followed by sedimentation. Coagulation consists of the addition of small amounts of certain chemical compounds, which react in the water to form fluffy particles, called flocs. Flocs grow in size by coalescence and adsorption of turbidity and bacteria particles on the surface. When these heavy flocs settle out under fairly quiescent conditions, they tend to "sweep out" undesirable particles of turbidity and bacteria.

In coagulation it is necessary to add the coagulating chemicals in controlled amounts. For this purpose, chemical feeders are used.

Filtration

Following coagulation and sedimentation for a period of some hours, the treated water is fairly clear, but it still contains small amounts of impurities. Therefore the water is passed through sand filters, where any remaining floc, turbidity particles and bacteria are removed. When the filter tends to become clogged with these impurities, water will not pass freely through the filter, and the filters must be washed free of the "dirt" that has collected. Operation of filters at the proper rates and the washing at proper times can be controlled manually or by automatic control devices.

Tastes and Odors

Tastes and odors in water do not make it harmful for human consumption but few water consumers want water with any tastes, odor or color. Removal of these undesirables is important, particularly in surface waters. Tastes and odors may be caused by growths of algae or decay of vegetation in reservoirs, or by industrial wastes. Algae treatment may be two-pronged: Copper sulfate treatment of reservoirs to kill algae growth and prevent tastes, and treatment to remove tastes and odors in water. Treatment may be accomplished either by the addition of finely divided highly adsorbent activated carbon to remove the taste and odor producing compounds, or by adding chlorine or chlorine dioxide to react chemically and destroy the taste and odor compounds.

Color, like tastes and odors, is also undesirable in water. It is usually caused by leaching of organic vegetable matter on reservoir sites. It is removed to some extent by coagulation, and filtration, or by activated carbon and sometimes by chlorination.

Disinfection

The primary responsibility of a water utility is to supply its customers with potable water and the primary requisite of potable water is that it be free from disease producing bacteria. Although coagulation, sedimentation and filtration remove practically all bacteria, it is the process of disinfection that completes the job and insures the safety of a water supply.

Chlorination is the most common method of disinfection, although ozone, and ultraviolet light have been used in a few instances, particularly in Europe. In this country, the term "disinfection" is almost interchangeable with the term "chlorination."

There are practically no surface waters supplies that are not chlorinated and many well supplies are chlorinated as a precautionary measure. In the larger plants, chlorine is added to water as a gas dissolved in water. Chlorine gas feeders are used for this purpose to control the dosage and at the same time assure against possible leakage of the gas. In small plants, disinfection may be accomplished by feeding solutions of calcium hypochlorite. This process is usually called hypochlorination to distinguish it from chlorination with chlorine gas.

The process of chlorination has a terminology of its own relating to the point of application, method of control, and kind of residual existing after the process is complete. The method of action of chlorine, extent of kill, effect of chlorine on viruses,

bacteria, and spores, the prevention of aftergrowth in mains, and the disinfection of new mains are all important phases of the process.

Fluoridation

In 1945, two experimental installations were made for the addition of 1.0 ppm of fluoride ion to community water supplies as a means of reducing tooth decay. It was the purpose of these installations to study the effect of artificially fluoridated water supplies on the incidence of dental caries in children. Previous studies on residents of communities using water containing naturally occurring fluorides in amounts of about 1 ppm had shown that persons drinking such waters had far less tooth decay than persons whose water supplies contained no fluorides.

Results at experimental installations were successful in the first few years and it was indicated that tooth decay in children drinking artificially fluoridated water decreased by 47 to 60 per cent. Endorsement of the idea of fluoridation by the Amer. Dental Assn., The Amer. Medical Assn., and the U. S. Pub. Health Service, among others, led to many other installations.

Chemicals used are sodium fluoride, sodium silico-fluoride, hydrofluosilic acid; the chemical is added to the water by carefully controlled chemical feeders. A maximum of 1.2 ppm is added in winter and somewhat less than that in the summer months.

Softening

When water contains relatively large amounts of calcium and magnesium in combination with bicarbonate, chloride or sulfate, that water is said to be "hard." It will make curds with soap, will produce undesirable "rings around the bathtub," will consume quantities of soap without forming suds, and will deposit scale and sludge when boiled or converted to steam. All of these effects are undesirable in both home and in industry.

To overcome these objectional features, water is softened in two ways: By the addition of lime (or lime and soda ash), or by passing the water over a bed of ion-exchange material. In the lime or lime soda process, the calcium and magnesium are removed by precipitation as calcium carbonate and magnesium hydroxide, followed by sedimentation and filtration. In the ion-exchange process, the ion-exchange material has the ability to give up sodium ions in exchange for the calcium and magnesium ions thus leaving the water soft as far as soap consumption is concerned. This does not reduce the total concentration of salts in the water. If reduced chemical content is desired, several combinations of ion-exchange materials may be used with the result that water can be practically completely freed of dissolved salts. This process is known as demineralization.

Iron and Manganese

In some localities, ground water contains iron in the form of ferrous bicarbonate. Some surfaces may also contain iron compounds. When present in amounts greater than 0.2 ppm. it is undesirable and will cause rust stains in household fixtures and brown spots in laundered goods. Higher concentrations are worse. Red water is caused by iron dissolved from iron pipe lines by the corrosive action of water.

To remove iron, the water is usually aerated and passed over a coarse filtering material such as coke, where the iron is precipitated. Combinations of coagulation, aeration, and softening can also be used.

Like iron, manganese in small concentrations will cause black stains on laundered clothes and on household fixtures. Some well water contain manganese; it is also found in surface supplies taken from reservoirs, especially when the soil contains manganese and there is vegetation on the reservoir bottom to decay and produce organic and carbonic acids. Manganese may be removed from water supplies by a combination of raising the pH and aerating, or by chlorination and filtration or by coagulating with ferric salts.

Treatment for corrosion control includes neutralization and pH control in the case of acidic waters or the addition of small amounts of the glassy phosphates (sodium hexametaphosphate) to prevent corrosion by the deposition of a layer of protective phosphate on the pipe surface. Carbon dioxide can be removed by aeration. The deposition of a microscopic layer of calcium carbonate on pipe, either under the influence of water softening reactions or by cathodic protection will likewise minimize corrosion.

Chlorinated supplies should have equipment for determining the amount and type of chlorine residual. Surface water supplies, which employ coagulation, filtration, and disinfection will need more elaborate testing, including control tests of chlorination, and bacteriological tests on both raw and filtered water. Water softening plants will require other tests. Most surface water supplies also determine turbidity and alkalinity and tastes and odors. Reservoirs troubled with algæ sometimes require microscopic tests for control purposes.

SEWAGE WORKS PRACTICE

While the distribution system of a water utility carries water under pressure to the consumer through a network of pipes and valves, the sewer system collects the same water after use, in a network of sewer lines. The dirty water in the sewers is not under pressure and flows by gravity to the final point of disposal. Sewer lines do not contain any valves, but do have manholes at intervals to admit men and equipment for cleaning. As has been pointed out previously, pumping, flow measurement and instrumentation and control are important functional operations in sewage works.

Treatment

The purpose of sewage treatment is to protect public health and to prevent nuisance conditions in the receiving body of water. All receiving bodies have a limited ability for carrying on treatment of sewage within themselves, and disposal by dilution depends entirely on that ability. When that capacity is overtaxed, it is necessary to build sewage treatment plants. The choice of processes and methods for sewage treatment will depend on the extent to which this natural capacity can be utilized and consideration must also be given to the uses of the receiving waters.

Primary treatment consists of the removal of solid particles from sewage by physical or mechanical means, i.e., screening, grit removal, grease removal, and sedimentation. Important aids to primary treatment operations include chemical precipitation, flocculation, removal of finely divided solids by aeration and vacuum flotation, and the removal of grease and fine particles by air flotation.

Secondary treatment is an oxidation or a wet burning process for the removal and stabilization of finely divided solids and colloidal matter of dissolved organic matter by means of air and the activity of living organisms.

The trickling filter and the activated sludge process are the fundamental and best known methods for

accomplishing secondary treatment. There are several important aids to secondary treatment which improve the efficiency of operation of trickling filters or activated sludge. Trickling filter operation aids include, pre-aeration, recirculation of filter effluent, roughing filters, chlorination, alternate double filtration.

Activated sludge operations and efficiency may be improved in several ways: Pre-aeration; tapered aeration or the adding of air in larger amounts at the inlet end of an aeration tank and lesser amounts along the tank as the sewage becomes oxidized; distributed input of sewage along an aeration channel while the air input is kept constant; high rate activation; and addition of chemicals, particularly an iron salt.

Contact aeration is a process whereby sewage is passed over surfaces on which biological growths develop while air is passed through the sewage. Practically all proprietary or patented treatment processes are some variation the basic processes of sedimentation and either trickling filtration or activated sludge.

Disinfection

Disinfection is the destruction of pathogenic or disease producing organisms; it is not sterilization which is the complete killing of all bacteria and other biological organisms. Disinfection is generally accomplished by the introduction of chlorine into the sewage or the introduction of a hypochlorite solution. Almost all modifications of the process of disinfection concern the point of addition of the chlorine, or the amounts of chlorine used. Chlorination also reduces B.O.D. to some extent, it controls odors, and it may be used to control sludge bulking in activated sludge and foaming in sludge digesters.

Solids Disposal

Solids disposal is not a sewage treatment process, in itself, but is a process for the treatment or handling of a by-product of sewage treatment. This by-product has a high nuisance character. In the general process of solids disposal, there are several minor problems, processes, and methods, depending on the particular solid matter being handled.

Screenings may be buried, burned, or ground and returned to the sewage flow for removal as sludge in the sedimentation tanks. Grit, which is usually a combination of sand, cinders, coffee grounds and miscellaneous items such as bottle caps, etc., may also contain large amounts of organic matter (food and garbage particles, leaves, paper, and sewage organic matter). If grit can be washed free of the organic matter or if it is relatively clean as deposited, it may be used as fill.

Grease presents a difficult problem. Its removal is messy and presents a problem in handling; it is usually burned in some crude incinerator; if it is organic in nature and discharged to sludge digestion tanks, it will digest, but if mineral in nature, it will not.

The organic matter that settles in sedimentation tanks, is called raw sludge. It is a highly noxious material, containing about 4 to 8 per cent solids which will begin to undergo decomposition in a relatively short time. Because of its high organic and bacterial content, raw sludge cannot be disposed of by spreading on ground or by burying. It can be discharged into large deep lagoons where it will undergo decomposition without nuisance conditions or it can be discharged into covered tanks where its decomposition can be controlled. In some cases sludge may be barged to sea.

Digestion, Dewatering, Incineration

When sludge is introduced into tanks in the absence of air and heated, it undergoes digestion. Gases, composed of methane and carbon dioxide are given off, the sludge assumes a black granular appearance and loses its nuisance characteristics. The concentration of solids in the sludge increases but the total amount of solid matter decreases by as much as forty per cent. When digestion is complete the sludge may be removed for ultimate disposal.

Digested sludge may be drained and dryed on sand beds, or dewatered by treatment with coagulating chemicals and filtered on vacuum filters, after which it may be dumped for fill in low areas; or it may be dried under the influence of heat after which it may be used as a fertilizer or soil conditioner. In some cases the vacuum dewatered sludge is burned in incinerators and the ashes used for fill. If the liquid sludge is washed before chemical treatment and vacuum filtration it is "elutriated."

Sludge from activated sludge treatment may be digested or filtered and dried directly for use as a soil conditioner. The humus material which sloughs off of trickling filters also may be sent to digesters or to drying and fill.

Miscellaneous Problems

As in the case of water works practice, preventive maintenance is an important part of proper operation. Sewer cleaning; cleaning sand out of settling tanks and digestion tanks; and lubrication programs are a part of maintenance. Laboratory control is very important.

Stream pollution is an important part of sewage treatment, and the studies necessary to understanding the capacity of receiving waters are complex and varied, involving such things as aquatic microbiology, oxygen depletion, reaeration, and other factors.

Industrial Waste Treatment

With more than 10,000 industries discharging wastes in the United States, it is apparent that the complexity and size of the problem is of major proportions. Industrial wastes have been classified according to source, or as inorganic, organic, etc. Generally, inorganic wastes will respond to treatment involving chemical and mechanical processes, such as sedimentation, filtration, etc. Organic wastes usually require treatment by biological processes and may or may not require chemical and mechanical processes.

There are certain basic unit processes of industrial waste treatment some or all of which may be used depending on the source of the waste. Almost all of these unit processes are the same as used in sewage treatment. For that reason, a fundamental knowledge of sewage treatment processes and results is necessary to handle the problems of industrial waste treatment.

Literature

The literature of water and sewage works practices is found in the journals of the technical associations such as the Am. Wat. Wks. Assn. and the Fed. Sew. & Ind. Was. Assns., in current technical magazines, and in reference publications such as the Reference & Data Edition of WATER & SEWAGE WORKS. There are also many books and manuals written on general and specific phases of the subject of water and sewage treatment. Lists of the most important books have been compiled by the Editors of WATER & SEWAGE WORKS magazine.

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Bureau of Sanitary Engrg.
State Dept. of Health
Austin, Texas

Utah
L. M. Thatcher, Chief
Bur. of Sanit. Engr.
State Dept. of Health
Salt Lake City 1, Utah

Vermont
E. L. Tracy, Chief
Bureau of Env. Sanitation
State Dept. of Health
Burlington, Vermont

Virginia
E. C. Meredith, Director
Div. of Engineering
State Dept. of Health
Richmond 19, Virginia

Washington
E. C. Jensen, Chief
Div. of Engrg. & Sanitation
State Dept. of Health
Seattle 4, Washington

W. Virginia
J. H. Millar, Director
Div. of Sanitary Engrg.
State Dept. of Health
Charleston 5, West Virginia

Wisconsin
O. J. Muegge, Director
Sec. of Env. Sanitation
State Board of Health
Madison 2, Wisconsin

Wyoming
A. E. Williamson, Director
Div. of Env. Sanitation
State Dept. of Public Health
Cheyenne, Wyoming

Public Health Service Field Offices

S. C. Martin, Regional Engineer
L. M. Klashman
Asst. Regional Engineer
Water Supply and Water Pollution Control Activities
Public Health Service
42 Broadway
New York 4, New York

C. H. Atkins, Regional Engineer
L. W. Gebhard
Asst. Regional Engineer
Water Supply and Water Pollution Control Activities
Public Health Service
700 East Jefferson Street
Charlottesville, Virginia

H. W. Chapman, Regional Engineer
L. A. Young
Asst. Regional Engineer
Water Supply and Water Pollution Control Activities
Public Health Service
50 Seventh Street, N. E.
Atlanta 23, Georgia

D. W. Evans, Regional Engineer
H. W. Poston,
Asst. Regional Engineer
Public Health Service
69 West Washington Street
Chicago 2, Illinois

G. J. Hopkins, Regional Engineer
L. B. Dworsky
Asst. Regional Engineer
Public Health Service
911 Walnut Street
Kansas City 6, Missouri

E. C. Warkentin, Regional Engineer
K. S. Krause
Asst. Regional Engineer
Water Supply and Water Pollution Control Activities
Public Health Service
1114 Commerce Street
Dallas 2, Texas

Edmund Garthe, Regional Engineer
J. H. Fooks
Asst. Regional Engineer
Public Health Service
Nineteenth & Stout Streets
Denver 2, Colorado

R. W. Hart, Regional Engineer
R. F. Poston
Asst. Regional Engineer
Water Supply and Water Pollution Control Activities
Public Health Service
447 Federal Office Building
Civic Center
San Francisco 2, California

H. C. Clare, In Charge,
Pacific Northwest Water Supply and Water Pollution Control Activities
Public Health Service
620 S. W. Main
Portland, Oregon

Directory of State and Interstate Water Pollution Control Agencies

Alabama
Arthur N. Beck, Technical Secretary
Water Improvement Commission
State Department of Health
Montgomery 4, Alabama

Alaska
Dr. H. V. Gibson, Exec. Secy.
Water Poll. Cont. Bd.
Alaska Office Bldg.
Juneau, Alaska

Arizona
C. W. Marx
Director & Chief Engr.
State Dept. of Health
Phoenix, Arizona

Arkansas
Glen T. Kellogg, Executive Secretary
Water Pollution Control Commission
State Health Bldg.
Little Rock, Arkansas

California
Paul R. Bonderson,
Executive Officer
State Water Pollution Control Bd.
1227 "O" St. Room 316
Sacramento 14, California

Colorado
William N. Gahr
Engineer-Director
Div. of Sanitation
State Dept. of Public Health
414 State Office Bldg.
Denver 2, Colorado

Connecticut
William S. Wise, Director
State Water Commission
165 Capitol Ave.
Hartford, Connecticut

Delaware
Dr. Donald K. Harmeson
Executive Officer
State Water Pollution Commission
Dover, Delaware

District of Columbia
Dr. Daniel L. Finucane
Director of Public Health
District of Columbia Dept. of
Public Health
Washington 1, D. C.

Florida
Dr. Wilson T. Sowder
State Health Officer
State Board of Health
Jacksonville 1, Florida

Georgia
Dr. T. F. Sellers, Director
Dept. of Public Health
Atlanta 3, Georgia

Hawaii
Dr. Richard K. C. Lee
President, Board of Health
Territory of Hawaii Dept. of Health
Honolulu 1, Hawaii

Idaho
Dr. T. O. Carver
Administrator of Health
State Board of Health
Boise, Idaho

Illinois
C. W. Klassen, Technical Secretary
Sanitary Water Board
Dept. of Public Health
400 So. Spring St.
Springfield, Illinois

Indiana
B. A. Poole, Technical Secretary
Stream Pollution and Control Board
State Board of Health
1330 W. Michigan St.
Indianapolis 7, Indiana

Iowa
Dr. Edmund G. Zimmerer
State Commissioner of Health
State Dept. of Health
Des Moines 19, Iowa

Kansas
D. F. Metzler, Director
Div. of Sanitation
State Board of Health
Topeka, Kansas

Kentucky
Louis F. Birkel, Executive Director
Water Pollution Control Commission
630 So. 3rd St.
Louisville 2, Kentucky

Louisiana
Kenneth E. Biglane, Exec. Secy.
Stream Control Commission
Box 9055, University Station
Baton Rouge 3, Louisiana

Maine
Dr. Dean H. Fisher, Secretary
Water Improvement Commission
State House
Augusta, Maine

Maryland
R. M. Brown, Chief
Bur. of Environ. Hygiene
State Dept. of Health
2114 North Charles Street
Baltimore 18, Maryland

Massachusetts
Dr. Samuel B. Kirkwood
Commissioner of Public Health
Dept. of Public Health
Boston 33, Massachusetts

Michigan
Milton P. Adams
Executive Secretary
Water Resources Commission
300 E. Michigan
Station B
Lansing 1, Michigan

Minnesota
Dr. R. N. Barr, Secretary
Water Pollution Control Commission
Dept. of Health
Campus, University of Minnesota
Minneapolis 14, Minnesota

Mississippi
Dr. Felix J. Underwood
Executive Officer & Secy.
State Board of Health
Jackson 5, Mississippi

Missouri
J. K. Smith, Exec. Secy
State Water Poll. Cont. Bd.
Division of Health
Dept. of Public Health & Welfare
Jefferson City, Missouri

Montana
Dr. G. D. C. Thompson
Act. Executive Officer
State Board of Health
Helena, Montana

Nebraska
Dr. E. A. Rogers
Director of Health
Dept. of Health
Lincoln 9, Nebraska

Nevada
W. W. White, Director
Div. of Public Health Engineering
State Dept. of Health
325 West Street
Reno, Nevada

New Hampshire
William A. Healy
Technical Secretary
Water Pollution Commission
Concord, New Hampshire

New Jersey
Dr. Daniel Bergsma
State Commissioner of Health
State Dept. of Health
Trenton 7, New Jersey

New Mexico
Dr. Stanley J. Leland
State Dir. of Public Health
Dept. of Public Health
Santa Fe, New Mexico

New York
A. F. Dappert Exec. Secy.
N. Y. State Wat. Poll. Cont. Bd.
State Dept. of Health
Albany 1, New York

No. Carolina
E. C. Hubbard,
Executive Secretary
State Stream Sanitation Committee
State Board of Health
Raleigh, North Carolina

No. Dakota
W. Van Heuvelen
Executive Officer
State Department of Health
Bismarck, North Dakota

Ohio
Dr. R. E. Dwork, Chairman
State Water Poll. Cont. Bd.
Dept. of Health
Columbus 15, Ohio

Oklahoma
Dr. G. F. Mathews
Commissioner of Health
State Dept. of Health
3400 North Eastern
Oklahoma City 5, Oklahoma

Oregon
Dr. Harold M. Erickson
State Health Officer
State Board of Health
Portland 5, Oregon

Pennsylvania
Dr. C. L. Wilbar, Jr., Chair.
Sanitary Water Board
Department of Health
Harrisburg, Pennsylvania

Puerto Rico
Dr. Guillermo Arbona
Secretary of Health
Department of Health
San Juan 18, Puerto Rico

Rhode Island
Dr. Edward A. McLaughlin
Director of Health
Department of Health
Providence 2, Rhode Island

So. Carolina
W. T. Linton, Executive Secretary
State Water Pollution Control Auth.
Caugham Bldg.
Columbia, South Carolina

So. Dakota
Charles E. Carl
Secretary & Executive Officer
Committee on Water Pollution
State Dept. of Health
Pierre, South Dakota

Tennessee
S. Leary Jones
Executive Secretary
Stream Pollution Control Board
Department of Public Health
Nashville 3, Tennessee

Texas
Dr. Henry A. Holle
State Health Officer
State Dept. of Health
510 E. Fifth Street
Austin 1, Texas

Utah
Lynn M. Thatcher, Exec. Secy.
Water Poll. Cont. Board
130 State Capitol Bldg.
Salt Lake City 1, Utah

Vermont
Rheinhold W. Thieme, Commissioner
State Water Conservation Board
Montpelier, Vermont

Virginia
A. H. Paessler, Executive Secretary
State Water Control Board
415 W. Franklin Street
Richmond 20, Virginia

Virgin Islands
Dr. Eric L. O'Neal
Commissioner
Department of Health
Charlotte Amalie, Virgin Islands

Washington
A. T. Neale, Act. Dir.
Pollution Control Commission
408 Old Capitol Bldg.
Olympia, Washington

W. Virginia
Bern Wright, Exec. Secy.
State Water Commission
Charleston 1, West Virginia

Wisconsin
Theodore F. Wisniewski, Director
Committee on Water Pollution
State Office Building
Madison 2, Wisconsin

Wyoming
Dr. Franklin D. Yoder
Director of Public Health
State Dept. of Public Health
Cheyenne, Wyoming

Interstate Agencies

Bi-State Agency
Lief J. Sverdrup, Chairman
Bi-State Development Agency
915 Olive Street
St. Louis 1, Missouri

Delaware River
James H. Allen, Exec. Secretary
Interstate Commission on
the Delaware River Basin
Broad Street Station Bldg.
Philadelphia 3, Pennsylvania

New England
Joseph C. Knox, Secretary
New England Interstate Water
Pollution Control Comm.
72 Tremont Street
Boston 8, Massachusetts

N. Y., N. J., Conn.
Seth G. Hess
Director and Ch. Engr.
Interstate Sanitation Comm.
110 William Street
New York 7, New York

Ohio River
Edward J. Cleary
Exec. Dir. & Ch. Engr.
Ohio River Valley Water
Sanitation Comm.
414 Walnut Street
Cincinnati 2, Ohio

Potomac River
Ellis S. Tisdale, Director
Interstate Commission on
The Potomac River Basin
203 Transportation Bldg.
Washington 6, D. C.

Tri-State Comm.
H. L. Walster, Chairman
Tri-State Water Comm.
North Dakota Agricultural College
Fargo, North Dakota

Books and Reference Manuals

Suggested Library Material for Water and Sewage Works

by GEORGE E. SYMONS, Ph. D.

Editor, Water & Sewage Works

Title and Price (F=Free)	*Publisher*	*Author*

I. Books for All Water and Sewage Works

First Aid, Surgical and Medical 4th Ed. ($4.00)	Appleton-Century-Crofts, Inc.	Cole and Puestow
Glossary—Water and Sewage Control Engineering ($2.00)	ASCE, APHA, AWWA, FSIWA	
Handbook of Cast Iron Pipe, 2nd Ed.	Cast Iron Pipe Research Assn.	
Laboratory Manual for Water & Sewage Analysis, 3rd Ed. ($4.75)	McGraw-Hill Book Co.	Theroux, Malmann & Eldridge
Lime Handling, Application and Storage in Treatment Processes (F)	National Lime Assn.	Rudolfs
Modern pH and Chlorine Control, 13th Ed. (F)	W. A. Taylor Co.	Taylor & McCrumb
Pipe Friction Manual, 1954 Ed. ($1.75)	Hydraulic Institute	
Rural Water Supply and Sanitation, 2nd Ed. ($4.90)	John Wiley & Sons	Wright
Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 10th Ed. ($7.50)	APHA, AWWA, & FSIWA	
Water Conditioning Data Book, 4th Ed. (F)	The Permutit Co.	

II. Books for Large Water and Sewage Works

Civil Engineering Handbook, 3rd Ed. ($12.50)	McGraw-Hill Co.	Urquardt
Corrosion: Causes and Prevention, 3rd Ed. ($12.00)	McGraw-Hill Book Co.	Speller
Corrosion Handbook ($16.00)	John Wiley & Sons	Uhlig
Data Book for Civil Engineers, I—Design, 2nd Ed. ($16.75)	John Wiley & Sons	Seelye
Data Book for Civil Engineers, II—Specifications and Costs 3rd Ed. ($20.00)	John Wiley & Sons	Seelye
Data Book for Civil Engineers, III—Field Practice 2nd Ed. ($7.50)	John Wiley & Sons	Seelye
Engineering in Public Health ($9.50)	McGraw-Hill Book Co.	Babbitt
Freshwater Biology, 1918 Ed. ($12.00)	John Wiley & Sons	Ward & Whipple
Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works—Joint Comm. Rept. ($0.75)	ASCE, ABA, AWWA, APHA, NARUC	
Handbook of Applied Hydraulics, 2nd Ed. ($16.00)	McGraw-Hill Book Co.	Davis
Handbook of Chemistry and Physics, 39th Ed. ($12.00)	Chemical Rubber Co.	
Handbook of Chemistry, 9th Ed.	Handbook Publishers, Inc.	Lange
Handbook of Hydraulics, 5th Ed. ($8.00)	McGraw-Hill Book Co.	King
Hydraulic Tables 3rd Ed. ($4.50)	John Wiley & Sons	Williams & Hazen
Industrial Water & Industrial Waste Water, Continuous Analysis of, 1953 Ed. ($1.50)	Am. Soc. Test. Mtls.	
Introduction to the Bacteria ($6.00)	McGraw Hill Book Co.	Clifton
Mechanical Engineers' Handbook, Power Volume, 12th Ed. ($10.00)	John Wiley & Sons	Kent-Salisbury
Microbiology, 2nd Ed. ($7.50)	Appleton-Century-Crofts, Inc.	Kelly and Hite
Plane Surveying ($6.75)	John Wiley & Sons	Tracy
Practice of Sanitation ($8.00)	Williams & Wilkens Co.	Hopkins & Schulze
Public Health Engineering, Vol. I ($8.50)	John Wiley & Sons	Phelps
Public Health Engineering, Vol. II ($5.50)	John Wiley & Sons	Phelps
Pump Handbook ($4.00)	*The* National Press	Finch
Pumps ($6.50)	McGraw-Hill Book Co.	Kristal & Annett
Rainfall and Runoff ($10.00)	*The* Macmillan Co.	Foster
Rosenau Preventive Medicine and Public Health	Appleton-Century-Crafts, Inc.	Maxcy
Specifications and Law on Engineering Works ($6.50)	John Wiley & Sons	Sadler
Standards of the Hydraulic Institute, 10th Ed. ($4.75)	Hydraulic Institute	
Standard Mathematical Tables, 10th Ed. ($3.00)	Chemical Rubber Co.	
Standard Practices for Low and Medium Speed Stationary Diesel Engines, 4th Ed. ($5.00)	Diesel Engine Mfrs. Assn.	
Water Supply and Waste-Water Disposal ($16.00)	John Wiley & Sons	Fair & Geyer
Zinsser's Bacteriology, 11th Ed. (1951) ($12.00)	Smith & Conont	

III. Books for Small and Large Water Works

Fluoridation as a Public Health Measure ($4.50)	Am. Assn. for Advance of Science	Shaw, et al
Legal Guide for Water Works Men ($1.00)	Case-Shepperd-Mann Div., R.H.	Donnelly Co.
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co.	Hirsch
Manual for Water Works Operators, 3rd Ed. ($5.00)	Tex. Wat. & Sew. Wks. Assn.	Billings, et al
Operation of Water Filtration Plants of Mechanical Gravity Type—Bul. No. 484 ($1.00)	San. Eng. Div., No. Car. St. Board of Health	
Taste and Odor Control in Water Purification, 2nd Ed. (F)	Industrial Chemical Sales Div., W. Va. Pulp & Paper Co.	

Title and Price (F=Free)	*Publisher*	*Author*
Water Supply and Treatment, 8th Ed. ($2.00)	National Lime Assn.	Hoover-Riehl
Water Works Operation ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Water Works Questions and Answers ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	

IV. Books for Small and Large Sewage Works

Control of Sludge Quality ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Controlling Roots in Sewers, Spec. Rept. No. 5 ($1.00)	Am. Pub. Wks. Assn.	
Handbook of Cast Iron Pipe, 2nd Ed. (F)	Cast Iron Pipe Research Assn.	
Laboratory Control of Sewage Treatment ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Manual for Sewage Plant Operations, 2nd Ed. ($6.50)	Tex. Wat. & Sew. Wks. Assn.	Billings, et al
Manuals of Practice (I-VII)	Fed. Sew. & Ind. Dept., Wastes Assn.	
Practice of Sanitation ($8.00)	Williams & Wilkins	Hopkins & Schulze
Principles of Sewage Treatment, 4th Ed. ($1.25)	National Lime Assn.	Rudolfs
Recent Developments in Chlorination Practice, Spec. Rept. No. 9 ($1.00)	Am. Pub. Wks. Assn.	
Sewage Treatment ($6.75)	John Wiley & Sons	Imhoff & Fair
Sewage Works Guide ($1.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	

V. Books for Large Water Works

Fresh Water Algae, 2nd Ed. ($12.50)	McGraw-Hill Book Co.	Smith
Ground Water ($9.50)	McGraw-Hill Book Co.	Tolman
Hydroelectric Handbook, 2nd Ed. ($17.00)	John Wiley & Sons	Creager & Justin
Hydrology ($7.50)	John Wiley & Sons	Wisler & Brater
Index to Journal AWWA— 1940-55 ($4.50) 1940-55 ($4.50)	Am. Wat. Wks. Assn.	
Laboratory Control of Water Purification ($4.00)	Case-Shepperd-Mann Dept., R. H. Donnelley Co.	
Manual of Water Works Accounting ($4.00)	Am. Wat. Wks. Assn.	
Manual on Industrial Water, 1957 Ed. ($7.50)	Am. Soc. Test. Mtls.	
Microscopy of Drinking Water, 4th Ed. ($12.00)	John Wiley & Sons	Whipple, Fair & Whipple
NFPA Handbook of Fire Protection, 11th Ed. ($10.50)	National Fire Protection Assn.	
Public Water Supplies, 4th Ed. ($7.75)	John Wiley & Sons	Turneaure & Russell
Survival and Retirement Experience with Water Works Facilities ($3.00)	Am. Wat. Wks. Assn.	
The Quest for Pure Water ($5.00)	Am. Wat. Wks. Assn.	N. M. Baker
Water Bacteriology, 6th Ed. ($5.25)	John Wiley & Sons	Prescott, Winslow & McCrady
Water Conditioning For Industry ($10.00)	McGraw-Hill Book Co.	Powell
Water Quality and Treatment, 2nd Ed. ($5.00)	Am. Wat. Wks. Assn.	
Water Supply and Purification, 3rd Ed. ($6.75)	International Textbook Co.	Hardenbergh
Water Supply Engineering, 5th Ed. ($8.50)	McGraw-Hill Book Co.	Babbitt & Doland
Water Supply and Sewage, 3rd Ed. ($8.75)	McGraw-Hill Book Co.	Steel
Water Treatment and Purification, 2nd Ed. ($5.50)	McGraw-Hill Book Co.	Ryan
Water Treatment for Industrial and Other Uses ($12.00)	Reinhold Book Division	Nordell

VI. Books for Large Sewage Works

American Sewage Practice—Vol. III—Disposal of Sewage, 3rd Ed. ($10.00)	McGraw-Hill Book Co.	Metcalf & Eddy
Biological Treatment of Sewage and Industrial Waste— Vol. I Aerobic Oxidation ($10.00) Vol. II Anaerobic Digestion ($10.00)	Reinhold Book Div.	McCabe & Eckenfelder
Industrial Waste Disposal Charges in Cities over 5000 Population, Spec. Rept. No. 18-S ($2.00)	Am. Pub. Wks. Assn.	Baffa, et al
Industrial Wastes, Their Treatment and Disposal ($9.50)	Reinhold Book Div.	Rudolfs, et al
Industrial Waste Treatment ($9.50)	McGraw-Hill Book Co.	Besselievre
Industrial Waste Treatment Practice	John Wiley & Sons	Gurnham
Principles of Industrial Waste Treatment ($9.50)	McGraw-Hill Book Co.	Eldridge
National Plumbing Code	U.S. Gov't Printing Office	
Recommended Minimum Requirements for Plumbing ($1.25)	Am. Soc. Mech. Engrs.	ASA-A-40.8-1955
Sewerage and Sewage Disposal, 2nd Ed. ($12.00)	McGraw-Hill Book Co.	Metcalf & Eddy
Sewage Service Charges in Cities over 5000 Population Spec. Rept. No. 18 ($2.00)	Am. Pub. Wks. Assn.	Tatlock, et al
Sewerage and Sewage Treatment, 3rd Ed. ($6.75)	International Textbook Co.	Hardenbergh
Sewerage and Sewage Treatment, 7th Ed. ($8.75)	John Wiley & Sons	Babbitt
Stream Sanitation ($6.00)	John Wiley & Sons	Phelps
Twenty-Year Index to Sewage Works Journal (1920-48) ($4.50)	Fed. Sew. & Ind. Wastes Assns.	Wisely & Symons
Uniform System of Accounts for Sewer Utilities ($5.00)	Fed. Sew. & Ind. Wastes Assns.	

VII. Technical Reports, Manuals, Bulletins and Reprints[1]

A. Useful in Both Water and Sewage Works

Chemical Lime Facts (F)	National Lime Assn.	
Conversion Factors for Engineers, 23rd Ed. (F)	Dorr-Oliver, Inc.	

(1) The U. S. Public Health Service, all State Health Departments, The Amer. Wat. Wks. Assn, Fed. Sew. & Ind. Wastes Assn., and most colleges of engineering have many manuals, bulletins, and reprints (at nominal prices) of interest to water and sewage plant operation. Also, equipment manufacturers offer free technical reprints on equipment and process operation in the fields of water supply and sewage disposal.

Title and Price (F=Free)	*Publisher*	*Author*
Financing Water Works and Sewerage Works Projects ($2.00)	Mo. Wat. & Sew. Conf.	Summers
Flow of Fluids Through Valves, Fittings and Pipe, 1956 Ed. (F)	Crane Co.	
Flow of Water in Cast Iron Pipe (F)	Cast Iron Pipe Research Assn.	
Keep Sheets of B-I-F Industries, Inc. ($1.00)	B-I-F Industries, Inc.	
Manual on Chemical Feed Machines, 1953 Ed. ($2.00)	Mo. Wat. & Sew. Conf.	Schworm
Manual on Consumer Water Rates, Part 1, 1952 Ed. ($2.00)	Mo. Wat. & Sew. Conf.	Miller
Principles of Handling Chlorine (F)	*The* Chlorine Institute	Langworthy
Public Relations Manual for Water Works and Sewage Works Operators ($2.00)	Mo. Wat. & Sew. Conf.	Magill
Safety Manual ($1.50)	Am. Wat. Wks. Assn.	
Specifications for Stationary Chlorine Storage Installations (F)	*The* Chlorine Institute	
The Chlorine Manual (F)	*The* Chlorine Institute	

B. Useful in Water Works

Copper Sulfate in Control of Microscopic Organisms, 1954 Ed. (F)	Phelps Dodge Refining Corp.	Hale
Drinking Water Standards ($0.10)	Govt. Printing Office	
Fire Engine Tests and Fire Stream Tables (F)	Nat. Bd. Fire Underwriters	
Operation and Repair of Water Facilities in Civil Defense Emergencies ($0.25)	U.S. Govt. Printing Office	
Pamphlets on Story of Water ($0.05 to $0.10)	Am. Wat. Wks. Assn.	
Producers and Repackagers of Chlorine in U. S. (F)	The Chlorine Institute	
Reprints of AWWA Committee Reports and Standards (order by number from list of AWWA publications)	Am. Wat. Wks. Assn.	
Silent Service Is Not Enough—Public Relations ($1.50)	Am. Wat. Wks. Assn.	
Water Chlorination, History, Development etc. (F)	The Chlorine Institute	Langworthy
Water Rates Manual ($1.25)	Am. Wat. Wks. Assn.	
Water Rate Structures in America—1940 Ed. ($0.25)	Pub. Serv. Comm. of Wisc.	
What Price Water ($0.10)	Am. Wat. Wks. Assn.	

C. Useful in Sewage Works

Copper Sulfate for Root and Fungus Control in Sanitary Sewers and Storm Drains, 1954 Ed. (F)	Phelps Dodge Refining Corp.	Phelps
Manuals of Practice Nos. 1,2,3,4,5,6 (various prices)	Fed. Sew. Ind. Was. Assn.	
Report of Committee of Great Lakes—Upper Mississippi River Board of State Sanitary Engineers—Bull. No. 42 ($1.00)	N. Y. State Health Dept.	

Addresses of Book Publishers

Publisher	*Address*
American Association for the Advancement of Science	1025 Connecticut Ave., N.W., Washington 6, D.C.
American Public Works Assn.	1313 East 60th St., Chicago 37, Ill.
American Society for Testing Materials	1916 Race St., Philadelphia 3, Pa.
American Society of Civil Engineers	33 West 39th St., New York, N.Y.
American Water Works Assn.	2 Park Ave., New York 16, N.Y.
Appleton-Century-Crofts, Inc.	35 West 32nd St., New York 1, N.Y.
B-I-F Industries, Inc.	345 Harris Ave., Providence, R.I.
Case-Shepperd-Mann Dept., R. H. Donnelley Co.	305 E. 45th St., New York 17, N.Y.
Cast Iron Pipe Research Assn.	Suite 3440, Prudential Plaza, Chicago 1, Ill.
Chemical Publishing Co., Inc.	212 Fifth Ave., New York 10, N.Y.
Crane Co.	836 So. Michigan Ave., Chicago 5, Ill.
Diesel Engine Manufacturers Assn.	1 No. La Salle St., Chicago 2, Ill.
Dorr-Oliver Inc.	Barry Place, Stamford, Conn.
Federation of Sewage and Industrial Wastes Assns.	4435 Wisconsin Ave., N.W., Washington 16, D. C.
Hydraulic Institute	122 E. 42nd St., New York 17, N.Y.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	230 Park Ave., New York 17, N.Y.
International Text Book Co.	Scranton 9, Penna.
John Wiley & Sons, Inc.	440 Fourth Ave., New York 16, N.Y.
McGraw-Hill Book Co.	330 West 42nd St., New York 36, N.Y.
Missouri Water and Sewerage Conference	State Office Bldg., Jefferson City, Mo.
National Board of Fire Underwriters	85 John St., New York 38, N.Y.
National Fire Protection Assn.	60 Batterymarch St., Boston 10, Mass.
National Lime Association	925 Fifteenth St., N.W., Washington 5, D.C.
North Carolina State Health Dept.	Raleigh, No. Carolina
N.Y. State Health Dept.	Albany 1, N.Y.
Phelps Dodge Refining Corp.	300 Park Ave., New York 22, New York
Public Service Commission of Wisconsin	State Office Building, Madison, Wis.
Reinhold Book Division	430 Park Ave., New York 22, N.Y.
Texas Water and Sewage Works Assn.	2202 Indian Trail, Austin, Tex.
The Chemical Rubber Co.	2310 Superior Ave., Cleveland 14, Ohio
The Chlorine Institute	50 East 41st St., New York 17, N.Y.
The Macmillan Co.	60 Fifth Ave., New York 11, N.Y.
The National Press	805 Hansen Way, Palo Alto, Calif.
The Permutit Co.	50 West 44th St., New York 36, N.Y.
United States Government Printing Office	Washington 25, D. C.
W. A. Taylor & Co.	7300 York Road, Baltimore 4, Md.
Williams & Wilkins Co.	Mt. Royal & Guilford Aves., Baltimore 2, Md.

Water Supply for Municipal Service

by JOHN H. MURDOCH, JR.
Consultant to
American Water Works Service Co.
Philadelphia, Pa.

■ THE MOST encouraging circumstance in the field of local water supply is that there is a widespread concern about it. If community and industrial leaders, state and local officials, business men, labor leaders and water consumers were perfectly satisfied about the adequacy of the local water supply to care for present needs and for needs foreseen, disaster would lie ahead. However, since there is concern—anxiety—about present conditions and the future, there is a realization of the need for action and there is, consequently, a probability that long-term problems will be solved. Complacency is the enemy of progress —concern is its harbinger. The quick and correct answer as to why the concern about local water supply is that most thinking people realize that water consumption is growing rapidly, that there are growing numbers of claimants on available supplies, that it takes years to develop new local sources of supply, and that something must be done now.

In this brief paper there will be mention of a few instances of personal experiences with local water supplies where there was a failure to provide for the future, with resulting hardship on consumers and losses to the business communities. The instances are chosen because they came within the writer's own experience and because they are representative and typical. Many more could be cited with reliance on published reports. The hardships resulting from the failure to make adequate provisions for growing demands prove the importance of a good water supply for all phases of the local economy. These instances of failure will be followed by a discussion of the function of a public water supply agency and of some of the major problems affecting them.

Supply Failures and Their Consequences

During the lifetime of the writer public water supply and health department officials have learned how to give to our urban population water which is safe to drink. Typhoid and other water-borne diseases have been practically eliminated where public water supplies are available. Prior to the early 1900's many public supplies were often highly dangerous to health, many times little if any better in quality than the common backyard wells and those wells were commonly sources of the recurrent and widely spreading typhoid epidemics. In fact, public supplies had little to commend them beyond convenience and the price of service was kept low to induce customers to take the poor service being offered. Today, with vastly improved service, officials have great difficulty in getting adequate financial support for the still better service now demanded because too many people still think that water should be cheap and that prices much higher than those based on the old dangerous conditions are exorbitant. Poverty traceable to this insistence on cheap water was the primary cause of the supply failures which will be mentioned and of the difficulties now met in building adequate systems.

Lack of Planning

In an eastern state one of the older, well established and prosperous communities had water supply difficulties beginning before 1890. The first public supply was drawn from a small creek, without storage, and it was soon found that storage of winter floods was essential to carry the load during the low stream flow periods. The storage provided would have been adequate in good rainfall years if there had been no growth of population and no new industries. The industries came, population grew, and rainfall was light. Result—periodic and long curtailments and even discontinuances of water supply. Industries were shut down, men were without work, all business suffered. At that time there were no health hazards involved because people never thought of drinking water from the public supply. They drank and took disease from the old familiar wells.

In 1900 a new organization took charge and correctly diagnosed the trouble. Greatly enlarged impounding reservoirs were created, a modern filter plant was built and waste of water was eliminated by putting all customers on a metered service basis.

False Economy

For reasons of economy only local engineering advice was secured for the supply system developments and long-term trends in growth of demand were not given adequate consideration. There were serious errors in calculations of reservoir capacities and failures to understand the effects of variations in stream flows with relation to required reservoir capacities to meet anticipated needs. With a supply safe for human consumption and with beautiful impounded lakes both domestic and industrial use expanded. The new supplies were adequate for twenty years of growth and —on the basis of the original and erroneous engineering figures—seemed good for several more years. There was no money available for expert advice on the adequacy of the supplies to meet growing needs. Then came disaster. Months of high demand—months of record breaking drought and continued reliance on figures of water in storage later found to be in error. At Christmas time state officials took charge of the situation. Water was allowed to flow from the dis-

The function of a public water supply agency is to provide water, where, when and as needed.

tributing reservoir into the city for only four hours a day. A fixed minimum was maintained in that reservoir for fire service. All industrial use was prohibited. Only essential domestic and commercial uses were permitted. State inspectors tested all wells and in most cases sealed them as unsafe for use. Industrially the city was brought to a standstill. No one talked of anything but the lack of water and of their hardships. Old friends dodged water works officials to avoid telling them their hard opinions. Only after many weeks could the restrictions be eased and service restored to some approximation of normal.

Equitable Solution

After that, with the backing of local bankers and other business men, expert water works men were employed and retained; new storage facilities were built and service rates were increased enough to carry the added costs. When the president of the largest industrial user was approached about the proposed increase in rates he studied his figures of increases in water expense to him and then stated that the increases would be infinitesimal compared with what it cost him to shut down during the shortage. The only assurance he wanted was that the new works were adequate. His attitude was typical of all customers. Management was now popular because service was the thing desired.

A Familiar Story

Ten years later another drought had practically the same effect on three other systems with which the writer is familiar. Supplies proved to be inadequate during periods of low stream flow; service was drastically curtailed; emergency supplies of poor quality were brought in to the distress of consumers; business suffered and unemployment was the result. In each case the local management, because of shortage of revenues and lack of sound expert advice from outside, had failed to make provision for the future in developing supply facilities, had failed to study drought cycles or to plot trends of water usage. Each one followed the short-sighted policy of keeping service cheap rather than adequate. It is probable that business losses alone during the periods of curtailed service exceeded the capital cost of the new facilities which were later provided.

A community can have adequate water service if it thinks and acts in the light of present-day conditions rather than of times when we drank from backyard wells.

Public Water for Urban and Suburban Areas

The following applies only to public water supply agencies, either municipally or privately owned, rather than to industrial or commercial supplies developed to care exclusively for the owner of the supply system. The latter are engaged in a private business rather than a public service. From the standpoint of available water resources of a district they are important and their adequacy and efficiency are important to community business health but their function and their problems differ from those of the public agencies.

Just what is the function of a public water supply agency in urban and suburban areas? Subject to important "ifs" which will be mentioned, it is submitted for your thought that the function of such a public water supply agency is to provide water, where, when and as needed. That is a big order and there are few agencies that meet it. Even after all proper allowances for the essential qualifications which will be expressed as "ifs" there are many failures to perform the function.

Let us take up the elements of the expression of function one by one.

Adequate Service

To provide water—where needed. A water system fails to meet this standard if its service be restricted to the closely built heart of the community, if it fails to expand its distribution facilities into the spreading suburbs as need for service arises and as developers and customers are ready and able to pay the necessary costs. A system which does not provide service when needs exist at high elevations and which sticks to the lowlands fails in its function. A system which cannot offer service to a new industry in new territory fails in its function. However, there are the qualifying "ifs" to consider later.

To provide water—when needed. Service which is available at hours when customers cannot conveniently use it but unavailable at convenient times is deficient service. Service which is adequate in winter or on moist, cool days but which is strictly limited on hot, dry days in summer when home owners need it to preserve their shrubbery, trees and lawns which cost money, is service which is deficient. Service which must be curtailed in periods of drought because of depletion of sources of supply is not truly adequate service. Our function is to supply water when needed and it is needed in periods of light rainfall at least as much as in normal periods. However, let us not forget the "ifs".

To provide water—as needed. The water should be available not only when and where needed but its quality must meet proper standards. In one of the instances of failure of supply which have been referred to an emergency source was tapped, high in acid and in hardness. The water furnished was better than no water but its use imposed real hardships on the community. That system did not furnish water as needed. Water service which is available only as a slow trickle and not at pressures and in flows adequate to meet the needs of customers under modern conditions of living and of industry, is not adequate service.

The "Ifs"

A public water supply agency can fulfill its function as stated:

(1) *If* wasteful use be eliminated. With the growth of population and the rapidly expanding use of water in industry and irrigation, there is not enough water to allow our people to waste it. Use must be limited to need—even waste for which users might be willing to pay the cost may well have to be prevented. So in the statement of function the emphasis is on "need" as distinguished from "wasteful use".

(2) *If* commercial, industrial and irrigation uses be kept in

realistic relation to practically available sources of supply. Where sources of supply, even if fully developed, are limited in quantity the public water supply agency should not be expected to offer service to new prospective big users of water which will cripple service to other customers. Local boosters should understand that not all communities can, in fairness to the public, take on enterprises requiring large quantities of water. A realistic balancing of potential demands against potential supplies is a necessity.

(3) *If* extensions of distribution system facilities be made under terms and conditions which do not require existing customers to subsidize the developers of outlying real estate. When new customers can be served only following additions to system which cost more than that on which the new revenue will yield a fair return the new customers are being subsidized by the older customers.

(4) *If* expert advice on financing, planning and operating the water works system be secured and retained. Unless the entire water works enterprise be guided by persons trained and skilled in the sciences and arts involved and unless these persons be dedicated to the rendering of adequate water service when, where and as needed, the community faces trouble, hardships and business loss. If such guidance be available and be followed adequate water service can be rendered.

(5) Finally—*If* the community be ready, willing and able to pay the cost of adequate service. Adequate service requires advance planning, development and constructon to take care of needs which will develop over the years. Adequate service involves provision for adverse conditions based on pessimistic appraisals of potentials. Such adequate service cannot be offered unless the community recognizes and acepts its cost—high in comparison with inadequate service or with the traditional cheap water which too many people cannot forget. A community can have adequate water service if it thinks and acts in the light of present-day conditions rather than of times when we drank from backyard wells.

Major Water Works Problems

The demand for water from public water works is growing tremendously. Increases in demands as measured by total annual pumpage range in the last ten years from twenty-five percent to upward of one hundred percent. Peak load demands have risen much more rapidly and these peak loads put real strains on a system. It has been necessary to increase investment in plant and property to care for these growths—increases of better than two hundred percent being quite common.

A major problem, then, is the physical one of finding adequate supplies in the face of mounting rival claims on total water resources. The second major problem is the securing of adequate funds to solve the physical problem. The third major problem is the securing and holding of the dedicated personnel required to plan, develop and operate an adequate system.

The final problem, and the one of which the solution would ease all the other problems, is the development of local community realization of the value and cost of a modern adequate public water supply.

Rate Making

For Water and Sewage Services

by ALBERT P. LEARNED

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Kansas City, Mo.

RATE MAKING is primarily the science of conversion into a schedule of monthly, bi-monthly or quarterly prices for units of service or commodity, by which the cost of service is collected from the customer using such service or commodity. It is through rates that a proper financial remuneration is secured from the customer. Such remuneration is intended to equitably reflect the cost of providing the service or commodity for the customer's use and, in most instances, reflects the customer's demand, commodity and customer costs. Rate making—or better, its accomplishments—has been decidedly in the public eye during the last few years.

Municipal as well as private water utilities have found it imperative in recent years to ask for increases in the rate schedule to combat rising costs. These rising costs have included labor, supplies and other materials required to build, operate and maintain a water system.

Costs of all types have increased; consequently, an increase in rates is the normal result in water system operations, unless rates were inordinately high prior to the ending of World War II.

A change in living conditions has added to both the operating and fixed charges for water utilities. The use of the automobile has broken down the objection to distances in cities. The suburban movement has resulted in a lower number of customers in the closer in residential areas than in prior years. Increased costs for water service are due to larger lots per individual house, requiring more feet of pipe between customers. This, in turn, adds to pumping and storage problems, as well as investment problems.

Although this article deals primarily with water rate matters, other utility rate-making comparisons will be made to show similarities and differences.

Cost of Service Considerations

Rate making, as stated earlier, is the method developed to secure the revenues required to meet the cost of service. There are certain conditions that have a vital effect on the cost of service, and particularly so if all costs of service are met with operating revenues. The fundamental items of cost of service in a private or municipal operation must include in some form:

1. Operating and maintenance expenses.
2. Taxes or their equivalent.
3. Annual allowance for depreciation of plant.
4. Return on plant in service.

The private water utility faces all of these costs, and the municipality faces practically all of them in one form or another. The municipal utility should be expected to meet its operating and maintenance expenses. It may escape taxes due to statutory provisions, but more often it faces an equivalent cost in the furnishing of fire protection service, for which the municipality pays only a nominal amount or makes no payment. The municipal water utility should collect the annual allowance for depreciation of plant. If not, it will find it has used up its plant and has not the original dollars available to replace the plant as it becomes needed, nor its equivalent in added plant. As a general rule, the municipality as a whole has the ownership of the plant vested in it. Under such conditions, it can expect a return to pay interest on outstanding debt. If more than sufficient for that use income can also be used for the amortization of debt.

In too many municipal utilities it has been the practice in the past to fail to collect more than a token payment on the last three items of the cost of service. A part of this fault has been the result, in many instances, of payment of debt requirements by general taxation.

Municipalities have in recent years, due to retarded tax legislation in part, realized that they could not further finance a water utility by general obligation bonds or assume the payments for such bonds, nor have they been able to secure sufficient funds through the accumulations in the depreciation reserve to meet current plant, and main extension requirements. The water revenue bond financing has, in general, filled this breach on major projects. The requirements of the bankers for extra coverage of debt requirements on such bonds have been such that the funds actually raised through rates often reflect in that coverage sufficient funds to provide for depreciation and for interest on more plant than is reflected by the interest charge on current debt. Such excess coverage can be used for current extensions, an accumulation in the depreciation reserve account, or earlier retirement of debt.

Many municipal water utilities have coasted along in the years immediately following the ending of World War II and exhausted all excess capacity in the system. Then, suddenly they have been brought face to face with a major expansion program.

Water Utilities' Problems

In the establishment of a water rate, it is important to recognize that the investment per customer can be very high in a water utility. This is invariably the case where the production plant involves extremely high expenditures per customer. Examples of high plant costs, are found in our semi-arid section of the country, where water is conveyed for long distances and the expenditure for the amount of supply distributed is very high. On top of that, we have a situation in the water works utility field which normally is not experienced to as aggravated a degree by other utilities. For instance, the water utility's peak occurs normally in the hot, dry period of the year when the source

of supply, if surface developed, is normally at its low point. The period of this high consumption is relatively short, particularly in the northern areas and tapers off somewhat in the southern areas. Contrasted with the situation of the water utilities are the gas and electric utilities. The natural gas system, which invites space heating because of convenience and economy, would have, if one considered only the residential use, a peaking situation not unlike that experienced by the water utility. However, gas usage is normally spread over a longer period in the year, and the utility can build up its off-peak load by sales for commercial and industrial use for which there are no corresponding sales in the water works industry. The electric utility has diversified use and certain types of load result in a much more satisfactory annual load factor. For instance, there are certain types of load which do not occur in the summer in such extremes as in winter and vice versa.

In both the gas and electric utilities, the demand for the production is increasing more rapidly than in the water works industry. There are advantages in the gas and electric utilities, from the standpoint of delivery of the commodity or service, more favorable than those which exist in the water works industry. For example, in the electric utility (by the use of higher voltages), the same size wire can be used to deliver substantially larger amounts of energy. In the natural gas industry where one is dealing with a compressible material, the effect of stepping up the pressure to establish distribution in intermediate pressure systems results in a substantial saving in the investment used for such service.

In the case of the water utility, the water being non-compressible produces higher friction losses with increased velocities than occur with gaseous fluids. It must be recognized that the water utility, marketwise, does not have the advantages of either gas or electricity, nor does it have the advantages from an operating standpoint that is possessed by these other two utilities.

The expression that "water is free" has lead to many misunderstandings in water rate making because the public did not realize that the operational costs in the preparation of the water to make it fit for human consumption and for delivery to the customer involves substantial charges that must be spread over fewer units of consumption than are required in the gas and electric utilities.

Important Rate Considerations

One of the important considerations in a water rate schedule is that the monthly minimum be sufficient to carry a reasonable share of the total cost of service. The water works industry in the past has been inclined to have a low minimum charge and often has not realized that 20 to 40 per cent of bills in smaller cities show a usage of 0 to 2,000 gallons per month, and that approximately 65 per cent of the bills are for 5,000 gallons per month or less. In large cities where there are a number of multi-family residences, approximately 50 per cent of the bills will be for 7,000 gallons per month or less.

Another important point has been that cities have not realized that water works systems have two primary purposes-one to provide fire protection, and the second to furnish water to the customers on the system. They have failed to realize the fire protection feature of the system, although it does not use large quantities of water, does necessitate the building of pumping plants, mains, storage facilities, and hydrants to insure adequate fire protection when needed, and does comprise a substantial portion of the investment in plant.

Another important consideration, particularly from the standpoint of the ability of the customers to pay and the public relations of the department, is the fact that too often water use is billed for on a quarterly basis and seem high to the customers, especially during the summer period. They fail to realize that the bill covers a longer period of time and compare it with their other utility bills, which are rendered monthly. A peculiarity of the American public is that it finds itself able to pay more easily if billed monthly than if billed for longer periods of time. The public, to an unconscious degree, is a budgeteer of his available funds and is likely to dismiss from consideration obligations that occur more frequently. It is often stated that money is saved by the less frequent billing, but there is some question whether such extra cost of frequent billing might not result in easier collections and less irritation to the consumers, even though the customers paid slightly more to effect the more frequent collection of his charges.

There has arisen in recent years one important water supply problem; namely, the use of non-conserved, air-conditioning units, which are a wasteful seasonal addition to the season's peak requirements. Where such conditions have been recognized and a rate has been provided to meet the situation, the annual surcharge per ton of refrigeration for non-conserved units has varied from $12.50 to $40. The amount of such a load and its effect on system operations differs in localities and in accordance with weather conditions, but is a substantial threat to satisfactory water service during peak periods because of its quantity requirements.

A conserved air-conditioning unit installation does not present a serious problem, since its usage is approximately 1/20th of the usage of the non-conserved installation.

The water works industry faces another peak load in the summer; namely, sprinkling, which is a heavy increase but because of diversification and scheduling, if necessary, can be much better handled than a non-conserved air-conditioning situation.

Other important considerations in arriving at a water rate for a particular utility involves a realization of the average sales in thousands of gallons per mile of main, the average investment per customer, and the probability of necessity for further expansion of the system within the immediate future.

Sewage Service Rates

In the field of rate making, there has developed within recent years the problem of sewage service rates, or charges to make safe the spent water supply of the community which may be discharged into a stream where there is an inadequate volume of water to receive the waste without the creation of a nuisance or a menace to public health.

In the development of sewage disposal rates there must be some consideration given to both the biological oxygen demand of the sewage and its volume, which results in a fairly uniform charge for single-family residences.

Volume consideration enters in multi-family residences to reflect the additional load, and there must be consideration given certain industrial wastes, which add a substantial amount to the cost of operation and construction of the sewage disposal plants because of the strength of the sewage.

Summary

Rate making necessitates an understanding of the problems involved, the reduction of those problems into financial equivalents, and the equitable distribution of those financial equivalents among the customers of the system.

Modernized Accounting and Service Procedures

by STANFORD I. ROTH
Collection Supervisor, Div. of Water and Sewers, City of Phoenix, Ariz.

NOTHING is quite as effective in stimulating modernization of operating procedures as skyrocketing growth. An excellent example of what can be done is seen in Phoenix, Ariz., where a doubling of the number of water customers since 1948 has resulted not only in economical, streamlined accounting and service procedures, but also in strong emphasis on good customer relations.

In 1952, it was realized that a new approach to these two related problems was the wise course. Therefore, a comprehensive study of policies, procedures, and equipment was undertaken.

The outcome has been establishment of bill collection substations (12 of them in drugstores — the long hours and seven-day operation being a factor in the choice); a unit bookkeeping plan, replacing the conventional ledger system; the reading of meters in even hundreds of cubic feet; a complete revision of the meter reading routes; a Kardex "customer service record"; direct telephone circuits linking the customer contact clerks to any desired unit bookkeeper or customer service record clerk; rate chart billing; and many other modernizations of related procedures.

Customer Satisfaction an Impelling Motive

The methods now in operation in Phoenix reflect today's trend on the part of American utility management

GENERAL VIEW of accounting, billing and collection office, Phoenix Division of Water and Sewers

towards placing customer satisfaction high on the list of operational objectives. Most customers having contact with a utility (beyond routine payment of bills) are either urgently in need of service, in the process of moving, annoyed by a supposed overcharge, or under request to rectify a past-due account. In any event, they are almost always on edge or upset to some degree.

It is at this crucial point that a contact clerk immediately able to marshal facts and figures can repair or cement public relations. The philosophy on which the modernization effort has been based is this need for faster, more accurate customer service. To further improve customer relations, a radio dispatch unit in the collecting office expedites transmission of the customer request for service to field representatives.

Office Modernization

Equipment, systems, and services supplied by Remington Rand have been instrumental in achieving many of these goals. The Kardex customer service record is housed in three insulated Multi-Cabinets having a capacity of well over 59,000 service locations (the present list tops 53,000). The file is set up alphabetically by street name, and then by street number. A 6 x 4 in. master card (the permanent office record for the location) provides space for permanent site information, plus turn-on and turn-off notations and posting of the current customer's name.

A traveling "service order" card (normally kept in the pocket with its related master card) has space for four complete service postings. The system enables one to track down, immediately, the status of any given service call, while the customer waits on the phone. One can also tell at a glance, by means of the notations and a system of movable colored signals, whether a location is on or off service, whether or not a meter is in place, and if so how soon it will be due for maintenance replacement. Temporary notations when the service order card is out complete the status record, keeping it immediately current—an important feature from both operational and customer relations viewpoints.

The "unit bookkeeping plan" is a stub accounting system that eliminates the usual ledger sheet. A portion of the customer's printed bill is the office record, and constitutes the accounts receivable. Cycle billing is employed to spread the work load evenly across the month.

Nine clerks are assigned to the job, including a central control bookkeeper and a lead bookkeeper. The former verifies the subsidiary records kept by the unit bookkeepers and maintains a set of master controls; the latter is responsible for supervising the section and completing the monthly cycle balancing of billing districts, within a predetermined work schedule.

Since each unit bookkeeper is responsible for all of her own customer records, the meter books, accounts receivable stubs, and paid stubs are housed in one insulated Safe-Desk per girl. This centralization of records that were once scattered throughout the department, plus the incentive of pride and responsibility inherent in the unit system, have yielded most encouraging results. After only a year the internal accounting control has been strengthened, a uniform basis

UNIT BOOKKEEPER has at a convenient working position the meter books, paid and unpaid bill stubs, and all records for the customers in her group. With drawers closed, the Safe-Desks are fireproof

tor evaluation of individual performance has been established, and—in line with the original objective—customer service has been greatly improved.

The Safe-Desks were selected for point-of-use protection of the vital records against fire, including the all-important receivables. These units are efficient work stations, the drawers opening wide, at a comfortable level, to expose all the stubs they contain; yet a quick shove slams them shut should the hazard of fire arise.

Redistricting Proves Boon to Billing

A much-needed part of the modernization program has been redistricting from 31 to 21 billing districts. The Business Services Department of Remington Rand carried out the work, starting with surveys and evaluations and winding up with the cut-over of the records to the new system.

An important feature of the new districting is that a continuous routing plan provides for absorbing future population expansion without disturbing the existing routing system or interrupting revenue. In addition, a smoother working schedule for customer accounting has been established with the elimination of peak loads in meter reading, billing, cost posting, and collection activity.

The study staff from Remington Rand started by verifying the basic records then in use, and carried out map work pertaining to districts and routes; estimated the effect of new districts on revenues; renumbered all affected records, and rearranged meter sheets accordingly; and prepared the street index for existing accounts. This done, they trained the utility employees in the use of the new system, thereby enabling progression to the final stage.

Customer contact desks have been provided for semi-private handling of customers. Clerks have been trained in interviewing techniques, and have learned to make full and rapid use of their links to the unit bookkeepers and customer service records. Each customer's request is given immediate and specialized attention in a more business-like and efficient manner.

As a result, this modernization program has developed more efficient customer service, has improved public relations, and has provided better working facilities. With all of this, it also has reduced operating costs.

Recommendation re Certification Policy of AWWA

1—AWWA should continuously increase the scope of, improve and modify its standards.

2—AWWA should so amend its standards as to require the supplier upon request of the purchaser of goods under these standards, to furnish a sworn certificate of full compliance with such standards.

3—AWWA recommends to its members that this certificate of compliance should always be requested if applicable. AWWA purchasers should be encouraged always to purchase "Per AWWA Standards" where available.

4—There has been discussion of certification of manufacturers. Some manufacturers may request certification. With that possibility in view it is recommended that the Secretary should take prompt steps to register a "mark" signifying made according to AWWA Standard."

5—That this Board, after affirmation by the Water Works Practice Committee, will enumerate those AWWA standards for which the mark will apply.

6—Upon receipt from manufacturers of a statement of willingness to furnish customers with certificates of compliance with such standards, AWWA upon request will issue a license to use the mark.

7—AWWA members should understand that the success of the certification program depends upon the members themselves.

8—Continuing permission to use the mark will depend upon the demonstrated good faith of the supplier.

Monthly Billing for Water Utilities

by A. VINCENT AGNEW

Supt. Water & Sewage Depts., Lorain, Ohio.

■ THE IDEA of monthly billing in the water works industry has been an intriguing one for several years. Investigation reveals that in Ohio (*1*), in cities of more than 15,000 population, the billing periods used are distributed as follows: semiannual, 5; bimonthly, 1; quarterly, 34; and monthly, 5.

In the semiannual group are found two of Ohio's largest cities and three in the 30,000 population category; in the bimonthly class, a city of approximately 20,000; in the quarterly group, cities with population ranges from 15,000 to 600,000; and in the monthly group cities in a population range from 20,000 to 35,000. It is quite obvious that monthly billing is not a popular method.

Sixty per cent of the water works industry is deficient in either supply, treatment facilities, or distribution, and the reasons for this condition are usually stated to be insufficient funds, low income because of low rates, inflation, and politics and politicians.

The electrical power industry on the other hand, does not show this efficiency in its facilities. At Lorain, Ohio, the power plant capacity was doubled in 1948, and is, at present, practically doubled again. In this same period, although the water plant doubled in size, there is still much to do in the distribution system. Power utilities are apparently foresighted enough to keep ahead of demand; they are in business for a profit and must pay dividends to stockholders. Publicly owned water facilities, which, theoretically, at least, need only break even, are put to shame by the program of expansion of the privately owned utility.

The explanation, of course, is finances, and finances mean rates, and rates mean collections. There are few, if any, privately owned power companies which bill and collect quarterly. Yet, it is obviously cheaper to bill and collect four times a year than twelve times a year. It is curious then, that big power utilities, which are in business for profit, continue to bill on a monthly or bimonthly basis when a cheaper method is available.

At first glance it would appear that the reason for not adopting a quarterly payment plan would be the cash turnover available under a monthly system. But this reason would apply only to the first quarter of such an operation, because, by establishing zones of payment and by cycling the billing, the monthly income would be the same (after the first quarter) as is now available on a monthly basis. From a financing standpoint, a monthly system is no better than a quarterly. With easier financing eliminated as a reason, and with the increased cost of monthly over quarterly billing, the reason must be better operation.

Public Relations

Good operation cannot exist without good public relations. By billing monthly, the bills are smaller, there is less delinquency and, consequently, less shutting off of service for nonpayment of bills. For the same reason, there are smaller overhead and service costs and—most of all—less public resistance to rate adjustments.

From the standpoint of public relations it is better to bill monthly, not only because of the smaller bills that result, but because the customer, knowing that he has a water bill due each month, will budget his payment the same as all other utility bills and will be able to compare the water bill directly to the gas or electric bill. Such a comparison would be very favorable to the water department in the vast majority of cases.

The steady per capita increase in water use resulting from the wide acceptance of automatic washers, garbage disposal units, automatic dishwashers, and air conditioning, has resulted in higher average water bills. This, together with summer sprinkling charges and sewage rental charges (adopted by more communities each year for sewage disposal financing) results, in many instances, in comparatively large summer bills, which, because of quarterly billing, fall due in November and December. Bringing the payment date closer to that of actual usage and allowing the customer to pay monthly rather than quarterly would do much to improve public relations—particularly in the period of excessive summer usage. By November and December, when the customer has completely forgotten how much sprinkling was done in July and August, and just before the holidays when other utility bills have began to increase after the summer lull, he is confronted with an exceptionally high water bill. Invariably he complains bitterly about the size of the water bill, stating, "Why I hardly sprinkled at all during July and August," or something such as "We were away on vacation part of the time."

Budget Plan

Gas companies in Ohio have inaugurated what is termed a "budget plant." Under this plan the annual gas bill is estimated and a prorated part of such estimate is paid each month. Adjustments based on actual meter readings are then made. This, of course, levels off the peak bills and results in an almost equal monthly payment all year. According to the local gas company, there has been eager acceptance of the plan indicating public preference for a budget system of payment. Nearly all advertising nowadays is based on this idea; prices are ignored, and just the monthly payment needed is given.

Quarterly billing is completely out of tune with the times, and it is time, instead, to adopt not only monthly billing but a budgeted plan also. The Bureau of Inspection of Public Offices of the State of Ohio Auditor's Office has indicated that there were no objections to such a billing system, provided that good records were kept. In

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other words if the utility's "housekeeping" is good there would be no objection to the plan.

Conversion Program

A study has shown that in Lorain adoption of monthly billing on a budget plan would require the following procedure. First, a change from the ledger plan to stub billing, followed by a classification of the accounts according to the amounts paid yearly by the various customers. An accounting addressograph machine would be purchased and each customer plate punched for the amount to be paid each month. The plates would then be fed into the machine which would tabulate the account numbers, the amount payable for water, sewer rental charges, the total of each, and a grand total. This record would constitute the accounts receivable ledger control. Such a machine will produce up to 3,000 bills per hour, automatically.

Present operation at Lorain is on a three-zone plan with billing cycled quarterly so that billing and collection are done each month. The payment period, without penalty, is from the first to the fifteenth of the month. On a monthly plan, billing would be cycled so that one zone would pay from the first to the tenth, another the tenth to the twentieth, and the third from the twentieth to the thirtieth. Up to the present, reading meters less than four times a year, as is now being done, has not been considered. Once the plan is put into operation, however, a frequency of two readings per year would be indicated, at which time the prorated bill would be adjusted. The adjusted bills would, of course, be run through the regular billing machine and the credits posted to the customer bill at that time.

The study indicated that no additional personnel would be needed to change from the present method of billing to the monthly budget plan. The only cost would be for the purchase of the equipment and the mailing charges. This cost could eventually be met by the swings of semiannual meter readings over quarterly readings. Even if the cost were greater, it is believed that intangible benefits would derive from the modernization of billing and collection by the adoption of the monthly billing plan.

Conclusion

Victor Weir said recently "Adequate income is the current prime problem for both publicly and privately owned water utilities. This is essential if rapidly expanding demands are to be met at today's inflated costs . . . and if adequate staffs are to be retained." He also stated, "It is difficult to educate John Q. Public that a financially healthy utility is to his best interest, but it must be done."

Since lack of sufficient income is the underlying cause of the industry's lagging behind demands made upon it and "John Q. Public is difficult to educate" then it must be made as painless as possible for Joe Smith to pay his water bill by adopting the monthly billing plan. Then, should rate adjustments ever be necessary, and they will be, a small monthly increase would be much more painless and much easier to sell than the same applied to an accumulation of three months of water usage.

It has always been surprising, when discussing "excessive" water bills with customers, that they seldom ever consider the fact that the bill is for 3 months' supply of water. The vast majority of people look upon a bill as an obligation of the moment with no thought given to the time of its accumulation. It is necessary, therefore, to increase the frequency of such moments. This may be accomplished by joining the public utility groups which bill and collect monthly. There is no better way for the water works industry to get the income needed to meet all the demands made on it. In the future, perhaps, the industry will find itself in the enviable position of the other large public utilities.

Reference

1. Bulletin on Water Rates in Ohio. Ohio Department of Health (1954).

Discussion

by Harry E. Jordan

Secy., American Water Works Assn., New York, N. Y.

The author has presented a stimulating study of the values derived from frequent reading of customer's water meters. The connection which he observes between advanced planning, adequacy of facilities, and frequency of meter reading, is not, however, as rigid as might be thought. There can be no question that advance planning of water supply facilities is greatly needed in many of the properties over the country. It is also evident that there is more than a casual relationship between the lack of advance planning on the one hand and the lack of facilities already installed to meet the customer's demands on the other hand.

The point in the author's paper which must be critically examined is the emphasis he places on the superior value of monthly billing—both as a matter of business and as good public relations. Some of the very best managed water utilities in the United States continue to read meters and bill customers quarterly; for example: Akron, Ohio; Birmingham, Ala.; Denver, Colo.; Detroit, Mich.; Miami, Fla.; Milwaukee, Wis.; New Haven, Conn.; St. Paul, Minn.; and St. Louis County (Mo.) Water Co. These properties are all well managed and keep abreast of the consumer demands, yet they continue, for reasons sufficient to their management, to read and bill quarterly. Beginning in the war years with the example of the very efficient Los Angeles Water Dept., meter reading and billing on a bimonthly basis has extended to such cities as Atlanta, Ga.; Chicago, Ill.; Gary and Indianapolis, Ind.; Kansas City, Mo.; and Louisville, Ky.

A persual of the AWWA survey of operating data for water utilities in 1955, published in the May 1957 JOURNAL (1), discloses a very substantial number of water utilities which continue to read meters monthly. Reference to Column 15 of Table 2 of the survey, which shows the percentage of unaccounted-for water, and to Column 10 of Table 3, which gives the frequency of meter reading, discloses the fact that there is no straight-line relationship between the two. One would hope that such a relationship existed, but the record does not so indicate.

Reference

1. STAFF REPORT. A Survey of Operating Data for Water Works in 1955. *Jour. AWWA*, 49:553 (May 1957).

Water Plant Records Are Important

by WALLACE GRANT
Chemist
West Virginia Water Service Co.
Charleston, W. Va.

TO THE MAN operating a water treatment plant, keeping records of the operation is sometimes regarded as so much "paper work". Given a proper understanding of the purpose of adequate record keeping, however, this attitude quite likely will change, especially when the operator realizes that one of the primary reasons he should have written records of plant operation is for his own protection, in case of any controversy, unjust criticism, or in the event of an epidemic in the community.

Efficient operation of a water plant would be difficult, if not impossible, in the absence of proper records. Aside from systematizing and improving operation, records furnish information as to how a certain situation was handled in the past, together with how successful this method was found to be. When an expansion or improvement is needed in the plant, records furnish the basis of the plans; they also provide the information needed to justify the expansion or improvement to the governing body, whether a commission, city council, or board of directors. Records have a legal standing, in case of disputes which might get into the courts of law[1].

Ed Note: This paper comprised a lecture by Mr. Grant before the Virginia Water & Sewage Works Operator's Short School held at Va. Polytechnic Ins't., Blacksburg, Va.

Suggested Form

In 1930 an AWWA committee on purification data and forms offered suggestions on records [4], the important portions of which were as follows:

1. The entire monthly report should be made on a single sheet exactly 11 inches wide and of sufficient length to meet all requirements. The reports can then be folded 8½ by 11 inches in size for binding or filing.

2. A 2-inch binding margin should be left on the left-hand edge, and at least ¼-inch margin be left at the top, bottom, and right-hand edges.

3. The report should be printed or reproduced on thin paper or tracing cloth, so that (prints) can be made.

4. No printing should be put on the back of the sheet.

5. Title should be placed in the upper right-hand corner.

6. Remarks should be made in the space to the left of the title.

8. In filling in the forms, entries under the head of *B. coli*, the fractional form should be used, the denominator indicating the number of tubes tested, and the numerator indicating the number of tubes positive. (In current practice the term "coliform bacteria" is used).

9. In making annual reports, the same general arrangements should be used, but the report should be separated into two sheets, grouping the physical and chemical data on one sheet, and that relating to microorganisms and bacteria on another sheet. The spacing and lettering should be larger than on the regular monthly report so that photographic reproductions can be made. Monthly averages should be reported. Maximum and minimum results should be for the maximum and minimum day only.

11. The committee realizes the impossibility of recommending a standard form that will meet the needs of every city. Each city finds it desirable to record certain data

that would be of no particular value to other cities, but in order to compare the work of one filtration plant with another it is very desirable, insofar as possible, that each city preserve the same order in making reports.

Types of Records Needed

The size of the water treatment plant will largely determine the form in which records are kept. In a small or medium-sized plant the following are useful:

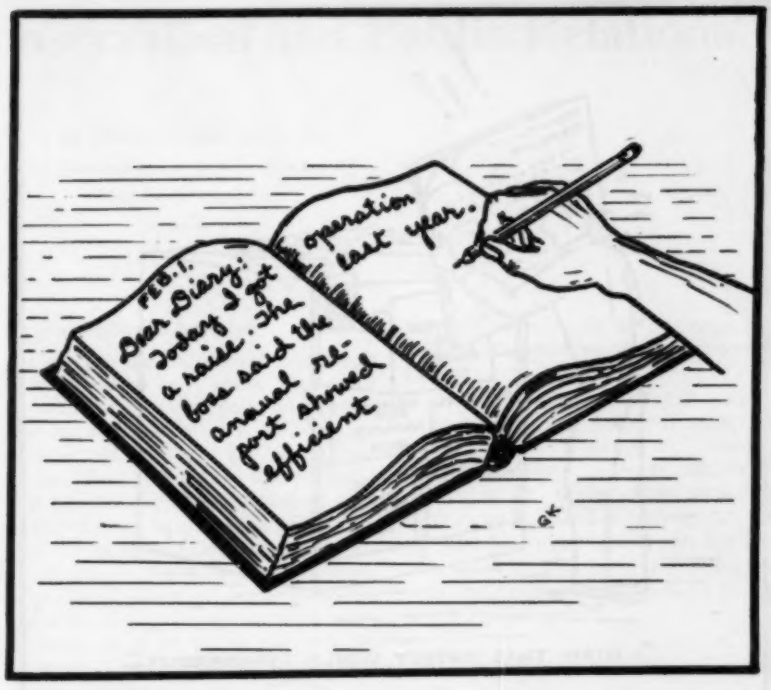
1. Daily log of filter operation, chemicals used, and such tests of water quality as determined by the operators.
2. Daily pump operation record.
3. A record of tests for residual chlorine, every hour or every two hours. The daily average is entered on the monthly report.
4. From the above a monthly or weekly report should be prepared for the record and to send to the State Department of Health.
5. A diary in which is recorded such information as will not readily fit any of the above forms.
6. An annual report.
7. A permanent file of instruction books, etc.

A good way to adapt forms for use in a plant is first to prepare them by mimeograph, or other method of rapid and easy reproduction, then use them a while, making corrections according to experience, before final forms are printed[1].

Daily Log and Pump Record

The daily log should show the amount of water pumped or filtered, the amount of water used in washing filters and for other plant use, the amount of chemicals needed for purification, the quality of the raw water, and the quality of the water leaving the plant[2]. It also should show when each filter was placed in operation after washing, which filters were washed, etc.

The results of daily tests made in the plant laboratory furnish a valuable record. The tests on raw water are helpful in adjusting the treatment of the water. Furnished water test results often will show the need for adjustment of chemical feeds in order to get the water quality closer to the ideal. For instance, a threshold odor test will show the need for improved odor control. Laboratory tests also furnish a record of water quality, which is both a protection to the water utility and satisfies the demand made by many water consumers. Calls often



are received from water consumers who wish to have a record of the water temperature, water hardness, and other mineral characteristics.

The daily record of chemicals used is the basis of all calculations of chemical cost per million gallons of water. Daily meter readings of power used and gas used enable the operator to keep a close check on the expense incurred by these items. The pump record should include the time each pump was started and stopped and the total hours each pump was used.

It is important that reports of a plant be studied at intervals to compare the efficiency with which the plant is operating[3].

The Diary

In the diary certain data should be kept which are essentially of a somewhat out-of-routine nature. The diary very properly could contain any or all of the following items:

1. Occasional numerical data and measurements, such as wash water rise on filters.
2. Repairs to a pump, valve, chlorinator, etc., or the replacement of any item in the plant.
3. Visits by officials of the company, water department, health department, labor department, or others, together with their remarks and impressions.
4. Start of any new operation, such as, for example, fluoridation.
5. Record of droughts or floods, and their effect on the plant.
6. Unusual difficulties in treatment, such as strong odor and taste in the raw water, and the measures found best to control them.

Monthly or Weekly Report

All important data from the daily log sheet and laboratory results should be included in the monthly report or the weekly report. These should include as many of the following items below as are available at the individual plant:

1. Water pumped or filtered.
2. Hours of operation daily.
3. Number of filters washed, together with hours filters operated between washes.
4. Wash water used.
5. All chemicals (in pounds) applied to water for each day's operation, together with the calculated dosage in parts per million, pounds per million gallons, or grains per gallon.
6. All chemical determinations, such as hardness, pH value, residual chlorine, etc.
7. All physical observations, such as turbidity, temperature, etc.
8. A complete record of all bacteriological examinations during the period.

Annual Report

If an annual report is prepared, it should show a compilation of the information in the monthly reports, with the average values of each for the year, together with the maximum and minimum days.

A brief narrative portion should be included which lists important events for the year, such as major improvements, new operations started, droughts, floods, and any other items of interest which, if not recorded here, could result in a frantic search for facts concerning them in later years. This could be a summary of items entered in the diary during the year. After a few years, items in a diary are quite difficult to find.

Permanent Records

Every plant, whether a large one or the smallest, should have a carefully preserved file of all instruction books, drawings, and other information furnished with each piece of equipment in the plant. It is surprising how many times a plant is visited where no instruction book is available for a piece of equipment purchased some years ago. Where this condition exists, usually a duplicate instruction book can be obtained from the manufacturer, often at no cost.

It is also a good plan to have name-plate data from various equipment items, collected, carefully copied, and placed on file at both the plant and the office.

Summary

Written records of water plant operation protect those operating the plant from unjust criticism, improve the operation by making available a check on efficiency, provide information on which expansion or improvements may be made, and have a legal standing should any dispute get into a court of law.

The American Water Works Association has, by committee, suggested standard forms for monthly and annual reports.

Suggested records to be kept by the water plant are as follows:

1. Daily log of filter operation, pump operation, and water quality tests.
2. Monthly or weekly report.
3. Diary.
4. Annual report.
5. Permanent file of all instruction books, name-plate data, and other information furnished by manufacturers of plant equipment.

Far from being just "paper work", careful records of water plant operation are essential for proper operation of a water works.

References:

1. Hirsch, A. A., "Manual for Water Plant Operators", Chemical Publishing Co. (1945).
2. Norcom, George D., and Broun, Kenneth W., "Water Purification for Plant Operators," McGraw-Hill Book Co. (1942).
3. Hopkins, Edward S., "Water Purification Control." The Williams and Wilkins Co. (1932).
4. AWWA Manual, "Water Quality and Treatment" (1950).

Management Conservation and Public Relations

by FRANK C. AMSBARY, JR.
Vice President & General Manager
Long Island Water Corp.
Lynbrook, L. I.

THE WATER RESOURCES Committee, of the Illinois Chamber of Commerce, in its beautifully edited brochure titled "Illinois Water Supply" states on page 17 "often, high turnover in municipal (water) department personnel results in a low level of competence. Increased management efficiency would largely avoid the following factors contributing to water shortages." This statement should be supplemented with . . . and would result in strictly business management methods being applied to an essential service which commands that approach.

As long as water departments are operated by the city council, it is not likely that there will be, completely, the type of operation to which the customers are entitled and have the right to expect, regardless of the competency of top management.

Wisconsin Leads in Management Efficiency

Wisconsin stands above all other states in efficiency of management because the municipal water systems in many of its important cities are controlled by boards of continuing personnel and policies and, to a greater extent than any other, the state requires that the operation of municipally owned water systems be subject to control of the state's Public Service Commission in matters of accounting, financial and engineering planning, and rates. It is also the custom for these municipally operated plants to pay to the city the equivalent of taxes paid by private property in the city and to receive from the city an appropriate fee for public fire protection. All of this creates good service, and friendly relations with the customers. Further, it results in qualified and competent personnel in management whose tenure is assured.

Ed. Note: This article is based on a paper presented before the Water Supply Conference of the Illinois State Chamber of Commerce. Published here by permission.

Typical Political Operation

Compare the Wisconsin setup with a hypothetical city where the water department is under political control. The superintendent is a political appointee and will hold his job as long as the "ins" are in. He has no background of the intricate problems that confront such a responsibility each day. If he is a fairly intelligent individual he will build up some knowledge over a period of years. Often he is not there long enough to reach such a status, or if he is, by the time he becomes seasoned and of some value to the department, the "ins" are out and so is he.

In this hypothetical city all money collected goes into the general city fund and the water department operates on appropriated funds—the city keeping all surplus for other uses. No provision for depreciation, engineering studies, no payment for fire protection, etc. A mere listing of these many abuses would almost fill a book, and they would not be hypothetical.

Burt Grant, Assistant Chief Engineer Water & Power of Los Angeles has this to say on this subject of political control. . . . "If a utility is to provide adequate water service it must not be subservient to any other function of municipal government. It must be operated in a proprietary capacity, having controls over its own funds: and it must collect from the municipality for all services rendered including public fire protection, at rates which at a minimum return all elements of cost".

Responsibility Without Authority

Responsibility for management staffing should be vested in the chief executive of the water works system. It is as much his duty to direct the procurement and development of managerial ability as it is for him to direct the mechanical operations of the enterprise.

While he may assign the duty of securing personnel with managerial ability to someone else, the ultimate responsibility for its development and subsequent performance remains with him.

Unless he does have full control over staffing of managerial posts the executive will be placed in a position of responsibility without authority, which is an unthinkable situation. Unless he has full authority to implement his responsibility, he has lost that much of his managerial influence over the conduct of the affairs of the water works system.

The Situation in Illinois

There have been bills presented to the Illinois legislature which would provide for a system comparable to that in Wisconsin, but they have never reached first base. There has been a powerful lobby actively seeing that such legislation is killed.

The Illinois Chamber of Commerce, or similar Civic organization would be doing the people of the state a distinct service if they would get actively behind such legislation. It will be an uphill battle. Enactment of such legislation is the basic step in promoting efficient water plant operation.

Unhampered, Intelligent Thinking Needed

The problems of water supply in the immediate future are going to be of a character that will demand intelligent thinking unhampered by political considerations, over a long period of time. It is an engineering problem and as time progresses it will become even more essential that professional engineers run the water plants. It will be almost impossible to attract the engineers skill that will be required unless this political stigma is removed.

A small insight into the magnitude of the problem confronting the water supply industry is provided by the following comparisons. In 1890 the average city used 95 gallons of water per person per day. This included domestic, industrial, commercial and municipal uses. Industry then and today meets much of its water needs in-

dependently of public systems. In 1950, the average city used water from the public system at the rate of 138 gallons per person per day. The annual rate of growth of customer use in the 1890-1950 period was 0.7 gallons per day, but by 1955 the rate of demand has grown to 145 gallons per person per day or a five-year annual increase in demand of 1.4 gallons per day. By 1965, it is estimated that the per-person demand will be 160 gallons per day and by 1975, 175 gallons per day.

With no increase in population this is a staggering increase in water usage. In 1950 our population was 152 million persons and it has been estimated by reliable sources assuming a continuation of a free unrestricted economy, by 1975 we will have not less than 206 million people in these United States. Increases in demand for water are 25 to 50% ahead of increases in population served.

Per capita usage and population growth is just one of the big problems facing the water supply industry and in part points to the fact that no water utility can afford less than top quality personnel who will be permitted to operate upon a strictly business basis.

To attract such men politics will have to be eliminated from the picture and compensation adjusted upwards so that the personnel is being adequately compensated for the responsibility they are expected to assume.

AWWA Recognizes the Problem

The following from the minutes of the Board of Directors of AWWA held May 12, 1957 should be of interest:

> ". . . observed that since the preponderance of water supply properties are under municipal control, the salary level in the water works system is leveled down by the salary rates set up for public administration work. He expressed his personal opinion that (not proper consideration of the competitive situation between (other) employment and municipal employment . . . (and) the salary level is so low for public employees that it becomes practically impossible to obtain a competent employee."

Water Conservation

Conservation and economics go hand-in-hand and sometimes it is difficult to determine which are trying to be accomplished. The Illinois water brochure, in effect states, that Illinois is not short on available water, the trouble is having it when and where it is needed. Sources of supplies that years ago were described as inexhaustable have now been found to be limited. There may be more than adequate quantities miles away but the cost to get it where it is needed may be terrific. First, conservation measures are instituted and when that approach is exhausted and it is found necessary to go miles away, they should be continued so as to reduce the size and cost of such expansion, and the cost of transporting excessive quantities of water great distances.

The brochure further calls attention to conservation methods instituted by several cities relative to water use in air-conditioning. This is, of course, a conservation of water resources, but non-conserved water use in air conditioners is also an economic monstrosity. For example, one plant, had an over-all annual load factor of between 65 and 70 per cent, while the air-conditioning load at that same plant was found to average between 25 and 30 per cent. The water utility was having to maintain an excessive source of supply, water treatment plant, pumping equipment, and oversized distribution system that lay idle 66 to 75 per cent of the year to meet this short seasonal load. This type of operation cannot be tolerated and meet the economic precepts of good business.

This is one method of conservation that was featured in the brochure. However, every unusual or new type of usage deserves a special study and ways or means of seeing that conservation is practiced, or if that is not possible, the user should pay for the service rendered on a economically self-supporting basis. Just one of these, to mention the problem presented in some Illinois communities, is the canning plants. They lay idle except for a month, possibly two, when they require large quantities of water. They expect the water utility to furnish them at the established rates. Their demands should be studied. If conservation is not possible, they should be put on a demand-charge basis to relieve the rest of the water users the necessity of supporting that idle plant 10 or 11 months in the year, through the established metered rates. Study might disclose many methods and if placed on a demand-charge basis, management of the canning plant would undoubtedly work the problem out.

California Steel Mill Practices Conservation

A steel mill at Fontana, Calif., so successfully worked out the problem that their daily water requirements to produce one ton of steel is less than 1/50 the amount used in the average American steel mill. The basic lack of water to waste in the area where the mill is located has led the people associated with its operations to develop water conservation and water reuse to the utmost degree. Man's ingenuity can work out conservation methods wherever and whenever the situation demands. All that is needed is the incentive, whether it be lack of water, impending shortage or economics.

Management Efficiency Tests

The American Water Works Association has assigned the job of devising management efficiency tests to compare the adaquecy of local utilities to a task group for solution. The chairman of this group was told by one observer that due to the complexities and wide variations in source of supply, treatment and distribution in water plants throughout the country, grading would be impossible. The chairman's reply was that if it were difficult to set up a rating system they would do the job right away but inasmuch as it is impossible, it will take them a little bit longer.

There are no rule-of-thumb tests. The men working on this problem are top quality minds and will, within the not too distant future accomplish the impossible.

Public Relations

No utility may expect to successfully survive unless it continuously carries out an honest and sincre public relations program. An uninformed public is an indifferent one. Most indifference is usually the result of lack of knowledge. A public that does not understand your water problems, can hardly be expected to sympathize with them or cooperate in solving them.

Never before has the public played so important a role in determining what water works facilities will be built and improved; what services should be rendered and how much they will pay for them. Never before has there been so much need for friendliness and understanding between the purveyor and customer.

The record is dotted with unfortunate instances where water works projects are defeated by public referenda; court actions and marches on the City Hall by citizen groups as demonstrations of public displeasure over water shortages.

Perhaps one of the most publicized incidents occurred in a community in New York State where civic improvement groups in area developments protested shortage of water during this summer's heat spell; filed injunction suit against the City to halt further building construction until existing homes are assured of enough water; criticized the construction of a needed elevated storage which would serve peak demands; and took issue with engineering recommendations for solving the water shortage.

Without sound public relations planning, the utility will be living from crisis to crisis. It is a poor way to live. It is far better to plan ahead and work to prevent public relation fires than to always be on the jump to extinguish them.

Successful Public Relations in Denver

An example of what a good public relations job will accomplish is best exemplified by the story of Denver. It is an example for every city in the United States to emulate.

Complete studies were made of the long-term water needs by top-flight engineers and it was found that it would be advisable to place a 15-year plan before the people asking for 75 million dollars. This public referendum was carried by a 10 to 1 majority. The referendum was held after more than four months of a careful conducted information program in which the local newspapers and the Chamber of Commerce of the city cooperated, not only by support of its members, but by the loan of its public relations director to the Water Commission for the duration of that campaign.

It is highly recommended that every Chamber of Commerce keep in close touch with their local water problems and lend their aid whether it be for an increase in rates, or capital expenditures if the water department can fully justify the need.

Abstract of Policy Statement Regarding Recreational Use of Domestic Water Supply Reservoir

The factors involved in the protection of water supplies are so varied as to locality, size, and facility that a definite policy attendant to the ownership and control of reservoirs and their marginal areas has not been established by practice. The establishment of a specific overall policy is impracticable. Further, the water works executive must necessarily consider the implications of the varying attitudes of the public toward the utility's properties. This variation is wide when applied to privately-owned and publicly-owned properties. However, he must always bear in mind his primary responsibility to supply a safe and palatable water, Moreover, the location, purpose, and utility of reservoirs must be considered in reaching decisions concerning recreational uses. Reservoirs may be:

Equalizing Reservoirs—Reservoirs within the area served and delivering finished water ready for consumption to the distribution system.

Terminal Reservoirs—Areas providing end storage of water prior to treatment.

Up-Stream Reservoirs—Reservoirs providing storage of untreated water at various points in the watershed to provide or supplement the supply at the terminal.

It is considered generally that recreational use of "Equalizing" and "Terminal Reservoirs" and the adjacent marginal lands is inimical to the basic function of furnishing a safe and potable water supply to the system's customers, and should be prohibited.

Impounded or stored water in "Up-Stream Reservoirs" can be classed in three categories:

Class A—Water derived from an uninhabited or sparsely inhabited area, at or near the point of rainfall or snow melt collected in a storage reservoir, clean and clear enough to be distributed to the consumers with disinfection only.

POLICY—Safe practice in the water works field recognizes the necessity of permitting no recreational activity on the water and watershed lands in and about such storage reservoirs.

Class B—Water impounded from an area not heavily inhabited and allowed to flow from storage in a natural stream to the point of withdrawal and requiring treatment in varying degree in addition to disinfection.

POLICY—Limited recreational activities on such reservoirs and adjacent lands are considered permissible under appropriate sanitary regulations.

Class C—Water which has flowed in a natural stream before storage for a consideration distance, having received polluting materials from municipalities, industries, and/or agricultural areas; confined in a reservoir primarily for purposes of storage until such time as low stream flow makes the stored water necessary for the use of the downstream city; later allowed to flow from the reservoir to the tributary water works in an open stream accessible to the public; and requiring complete treatment.

POLICY—Recreation is considered permissible under appropriate sanitary regulations. The determination of the kind and extent of recreational use shall be the sole responsibility of the water works executive of the system involved whose primary obligation it is to provide a safe and potable water, and subject only to existing police powers.

The American Water Works Association registers its opposition to legislation permitting or requiring the opening of domestic water supply reservoirs and adjacent lands to recreational use. Control of water supply reservoirs must remain the prerogative of the water purveyor.

Water Meters are Advantageous*

Case histories show benefits of 100 per cent metering to water utilities

by H. G. GREER

Sales Engineer, Neptune Meters, Limited in Toronto, Ontario, Canada

WATER—one of the essentials of life—should be free to all. Yes, as free as when quietly resting in a lake, running in a river or babbling in a mountain brook. That it is free in either place will not be denied, yet when we come to utilize it for domestic purposes it will cost either money, time or labor and will have a fixed value per gallon.

Water cannot be obtained from any source without an investment that has a money value, be it either time or labor. If we go to the lake, river or brook, where it flows as free as the air we breathe, we cannot procure it and carry it home without labor, and we find it does cost something.

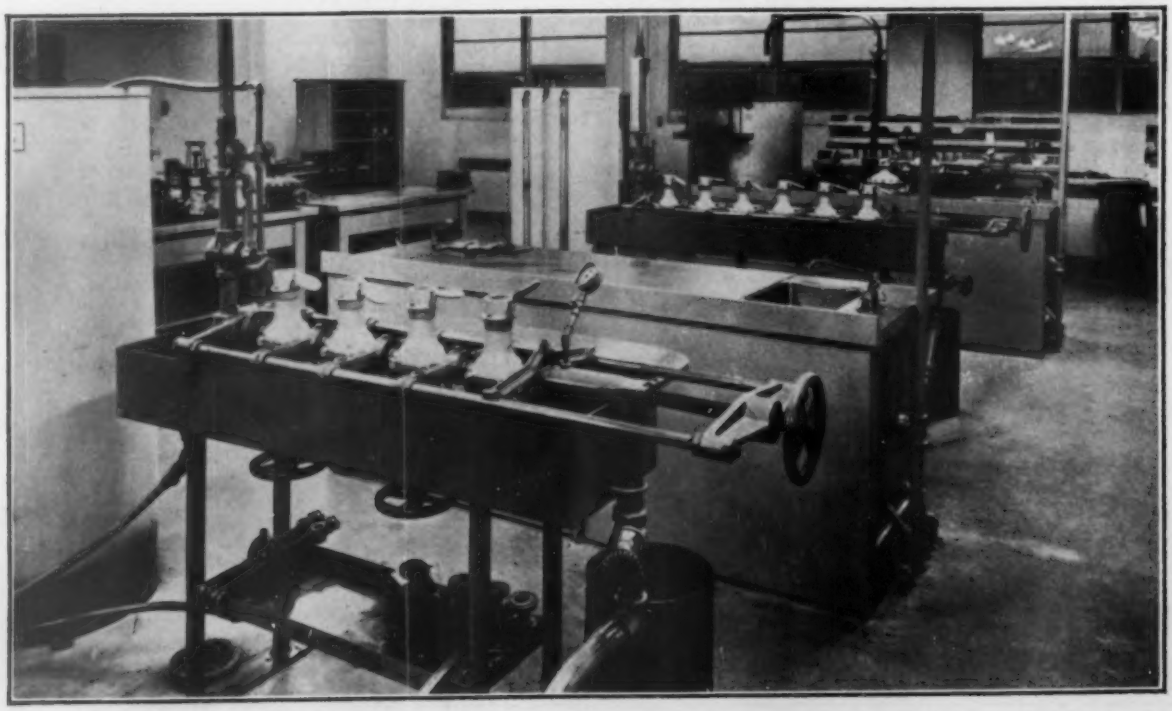
Under no circumstances can we obtain water without it having a fixed value represented by money, including the cost of pumping, filtration, addition of chemicals to make it fit for human consumption and the vast delivery system of water mains throughout the municipality to deliver it to each and every fixture in every home and every industry twenty-four hours a day. Standing by whenever it is needed, be it a glassful or thousands of gallons to put out a fire.

Metering is Equitable

Every good citizen will feel it a duty to pay his proportion of the cost for the convenience, the labor of taking care of the works, the chemicals to purify it and the interest on the money invested, etc. Theoretically, every consumer of water does assent to this, but practically he ignores it entirely. It is not infrequent for consumers to use many times the amount of water allotted to them, seeming to be utterly oblivious to the fact that they are doing a great moral wrong to their fellow citizens who are made to pay for their individual waste.

*A paper presented at the Western Ontario Water and Sewage Conference. Published here by permission.

METER test benches in water department—Edmonton, Alberta

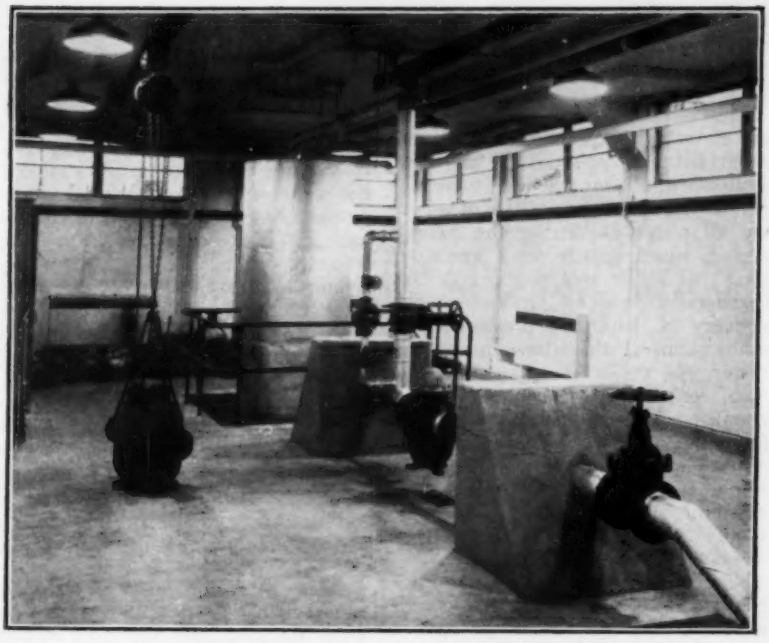


Often there is extravagance in the use of water, and like every other extravagance it is difficult to reform. It is but right that the use, purification and distribution of water, with all its blessings, should be subjected to the ordinary principles of equity and economy. No person will be charged for more than he consumes, nor will any be allowed to use water at the expense of his neighbor. This is accomplished by the use of a water meter. The water meter makes possible the establishment of a water rate fairest to each consumer. The water meter is the yardstick of the municipality, which registers in gallons or cubic feet as the case may be, in the same way in which you would buy gasoline for your automobile or a pound of sugar at your grocer's. The municipality requires a certain amount of money to operate for a given period of time, which they must collect from each consumer to pay for water mains, filtration plants, pumping equipment, the salaries of the personnel of the water department, sewage disposal plants, etc., and power to pump each and every gallon consumed or wasted. The consumer pays exactly the amount used and no one is required to pay for the carelessness of others. The equity of this is universally recognized in the case of electricity and gas.

The installation of meters on all services has proven a successful means of checking waste. A leaky toilet or faucet is no longer allowed to go unattended. It is repaired at the first possible opportunity, as the consumer soon realizes that a leaky fixture will pass many gallons that directly affect his pocketbook. Lawn sprinklers and hoses are allowed to run only long enough to do the necessary job of supplying sufficient moisture to keep the lawn in good health. The domestic consumer is not the only offender on a flat rate system, the same applies to the garage, dairy and other industries if services are not metered. The installation of meters on a former flat rate system usually results in a drop in the consumption of 30 per cent to 50 per cent.

Halifax and Milwaukee

Let us take as an example the City of Halifax. In 1905, according to Dr. Ira P. MacNab, Manager of the Public Service Commission of Halifax, the population of the City of Halifax was 35,400 persons having 6,939 services. At this time Venturi Meters were placed on the main supply lines to the city and it was found that the consumption was 11,370,000 gallons per day, or 320 gallons per capita per day. At that time only 5 per cent of the larger services were metered and the city was faced with the necessity of a large capital expenditure for additional supply mains or a very drastic curtailment in consumption. It was decided to install meters on all services, which was completed on and about 1913. The consumption immediately went down. In 1949 the daily consumption of water was 10,980,000 gallons per day to a population of 100,000 people, or 109 gallons per capita per day.



METER TESTING and repair shop, Edmonton, Alberta
Industrial meters are handled by overhead conveyors

The same applied to the City of Milwaukee, Wis. This city was a leader among the larger American cities to undertake general metering. This work started in 1887 when the demand virtually equalled the capacity of the supply intake and pressures were necessarily reduced. Meters were then installed on many of the larger manufacturing and commercial premises to curtail waste of water and thus relieve low pressures in the distribution system.

This metering reduced the per capita demand from 113 gallons per day in 1887 to 102 gallons per day in 1888. At this time, less than 20 per cent of the services were metered. As the metering increased, the per capita demand reduced, reaching a minimum of 80 gallons per day in 1901 when 89 per cent of the services were metered. This was a per capita reduction of 30 per cent without making any allowance for the yearly increase in the per capita daily demand. Since that time, the per capita demand in Milwaukee has shown a normal annual growth in line with the experience of other meter American cities.

Waste Reduced at Yarmouth, N. S.

The reduction in consumption and waste of water by the use of meters increases the storage facilities directly in relation to the population of a municipality, making more water available for additional consumers, fire protection and industry. The installation of meters on all services will conserve water resources and prolong, usually for years, the necessity and expense of drilling new wells, going further afield to a new supply with pipe lines until such a time when it is absolutely necessary to supply the consumers with a legitimate amount of water for all purposes.

A very good example of this is the Town of Yarmouth, Nova Scotia. In 1945 the town was faced with the necessity of replacing 8½ miles of pipeline from supply to pumphouse at a high cost, plus the possible necessity of additional supply. The situation was so serious that at times during the dry season water was not available for domestic or fire protection purposes in some sections of the town. It was decided to install meters on all services. The consumption immediately went down. Meters enabled the town to carry on supplying water

for every need for the past ten years, even with the addition of approximately 2,000 in population to that of 6,000 in 1945.

Meters do not limit the legitimate use of water. In practically all water departments a minimum bill has been established, allowing a fixed quantity per service to provide sufficient water for all purposes during the billing period, based usually on a family of four. All above this is charged for, based on the cost of production and delivery of water. In practically all municipalities, which have decided to meter, the public is opposed to the idea, feeling that it is going to be penalized for the use of water for legitimate purposes. This is not the case. The amount supplied with the minimum bill takes care of this. The wasteful consumer pays. The meter is the "Policeman of the Water Works," on duty at all times.

Controlling the consumption and the waste of water by the use of water meters will reduce the cost of operation of the sewage disposal plant. With less sewage to treat, less capacity will be required, less power used for pumping, making for a more economical operation. If a sewage plant was to be built to take care of 150 gallons per capita per day on a flat rate system, its capacity would be much greater than it would be to take care of 100 gallons per capita per day on a metered system. This would add additional burden to the tax rate.

St. Leonard, N. B.

By reducing the waste of water, more water is made available to each consumer when it is required. Using as a very good example, the town of St. Leonard, New Brunswick, having a population of 1,400 with 236 services. In 1950 there were times in the dry season when the water supply was exhausted. Meters were installed on or about that time and ample water has been available since, even with the addition of 20 to 30 new services, including a regional high school. This is a good percentage of increase in population for a town of this size. Master meters are not used on the supply, therefore consumption figures are not available.

Sudbury, Ont.

It is no doubt every water works engineers' desire to serve the greatest number of people with the least capital expenditure. This can only be accomplished by the use of meters controlling the consumption and enabling the water works to operate on a businesslike basis, decreasing the cost to each and every consumer. According to a report by R. H. Martindale, Water Works Superintendent, Sudbury, Ontario, "Sudbury is confronted with the need for expanding its water works system and has undertaken the replacement of old mains. To reduce waste we are working towards 100 per cent metering. A few hundred meters are installed each year, and now our system is metered except for 25 per cent of the domestic services. Our water consumption is about 70 Imperial gallons per capita per day."

Every water works official will agree that it is necessary to collect from the consumer sufficient monies to pay for the operation, interest, sinking fund and depreciation. The installation of meters will conserve the capacity of an existing water system, keeping the capital investment at a minimum, and this eventually means less cost of water to each consumer and eventually a reduction in the tax rate.

A metered water system enables the water works officials to determine and check the unaccounted for water by comparing the grand total registration of all meters against the registration of the master meters on the supply lines.

Cali, Colombia

A further example of metering results is provided by George C. Bunker, Consulting Engineer at National Institute of Sanitary Works, Caracas, Venezuela. Cali, in Colombia, South America, furnished an example of the effectiveness of meters in reducing the waste of water. The installation of meters was started in April, 1933. On December 31, 1934, 71 per cent of the services had been metered and the average daily consumption had dropped to 5,820,000 gallons or 38 per cent less than it was during March, 1933, although 967 new services had been added during the lapse of twenty-one months. On August 31st, 1935, 80.5 per cent of the 8,420 services in use had been metered and the average daily consumption had dropped to 5,250,000 gallons or 44 per cent less than it was during March, 1933, although 1,607 new services had been added during the lapse of 29 months.

The benefits resulting from the reduction in waste and leakage of water in Cali were as follows: the construction of four filters was postponed; the addition of settled water to the filtered water was stopped; expense for chemical treatment of the water was reduced; there was a marked increase in pressure in the central section of the distribution system during the daytime; and filters operated at a normal rate.

Port Hawkesbury, N. S.

The advantages of water meters apply in the same manner to all water systems, large or small. In Port Hawkesbury, Nova Scotia, a water system having twelve consumers is completely metered. Some years ago one of the citizens had a good well and was approached by his neighbors to supply them with water, to which he agreed. After a year or so his well did not have sufficient capacity to supply the consumption. Someone mentioned to him that if he installed meters on each service he would have plenty of water. This was done and since then they have never been short of water.

The necessity of conservation of water is a real one in this rapidly growing Canada of ours, with industry and population on a rapid increase. This, the Government of Ontario has already recognized, and has appointed four members to study the feasibility of supplying water, on a master plan, to southwestern Ontario from the Great Lakes. Whatever the source of supply required for this growing area, the installation of meters will benefit the system by keeping waste at a minimum and assuring that water used is paid for on an equitable basis.

Some Legal Problems in Water and Sewage Works

by JOHN H. MURDOCH, Jr.

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STATE CONSTITUTIONS and statutes provide a great store of detailed provisions governing the organization, financing, management, operation and ownership of both water and sewage systems, both publicly and privately owned, and concerning local and municipal government and public authorities and local self rule. Many legal problems in the fields of public water supply and sewage cannot be solved without consideration of the applicable state constitutions and statutes. This paper is not intended to cover this field. It is, of necessity, limited to the problems involving general legal principles.

Because it is in a distinct branch of law, the regulation of the rates charged by private companies engaged in rendering public water or sewer service will not be considered. In fact an effort has been made to limit the paper to matters in which there is no distinction between publicly and privately owned systems. The phrases "public water supply agency" and "public sewage agency" are used as meaning systems in both types of ownership. However, there is some comment regarding liability of public water supply agencies for fire losses and as to these there is a distinction in law based on the ownership of the system. General interest in the subject required the making of this exception in the coverage.

Since this article is written primarily for managers and staff associates in the agencies rather than for lawyers, and since it must be kept brief, citations of authorities are not given. There will appear here the author's conclusions or opinions on the law points covered based on his study of the authorities and on his experience in the field.

ED. NOTE: Mr. Murdoch prepared this article at our request as a brief summary and introduction to the subject of legal problems pertaining to water and sewage works. Persons interested in details of the subject with particular reference to water works should refer to the series of articles by the author on "Notes on Water Works Law" which have appeared in Water & Sewage Works during the past three years.

Water Works and Streams

Public water supply agencies are created and exist to perform a public function—to serve the public. As such they are in most cases vested with authority to secure a water supply from water sources within their state. When a public water supply agency uses a stream as a source of supply it lessens the flow in the stream and thus affects the interests of others having rights in the stream. These conflicts of interest are so frequent that an understanding of the legal principles involved is essential to water works management.

Riparian Rights

A tract of land through which a stream flows or which borders on a stream and which is in the watershed of the stream is riparian land and the owner of such land has riparian rights which are part and parcel of his riparian land. Those rights are property rights protected by the constitutions of the states and of the United States. The riparian rights include the right to have the waters of the stream reach the riparian land undiminished in quantity and unimpaired in quality except to the extent resulting from the "natural" uses of the waters by upper riparian owners or from such "artificial" uses as are considered reasonable under all the circumstances surrounding the particular use. The riparian rights consequently include the right to make use of the water on the owner's riparian land for the "natural" uses of domestic or household consumption and for stock watering even though such "natural" uses exhaust the stream. Riparian rights also include the right to make such reasonable "artificial" uses of the water as those involved in manufacturing and irrigation — in both cases on riparian land. As regards such so-called artificial uses the extent of use must be reasonable and that means generally that the use must be so related to stream flow as not to so deplete the stream as to

interfere with downstream natural uses or deny to downstream users for artificial uses equal opportunity for such use. In fact it appears that artificial use will be held to be unreasonable if it perceptibly diminishes the flow of the stream. What has been stated here applies to the states which follow the common law as to waters and which are the states in the humid sections. In the states in the arid and semiarid sections some form of the doctrine of appropriation for beneficial use applies and in some states a combination of common law riparian rights and of appropriation is in force. The two systems of water law are widely divergent. Much of what will be said here about rights in streams will have application only in the riparian rights states.

Diversion Authority vs. Riparian Rights

It must be kept in mind that riparian water rights are rights to use and do not involve ownership of the water. On the other hand the state, as trustee for the public, is the owner of the stream — the entity. Whether it owns the water or the bed of the stream appears to be unimportant—it has the right to control the stream and to have it continue in existence as a stream subject to the property rights of the owners of riparian land. From this legal principle it follows that the state and only the state has the legal power to authorize diversion of flowing water for other than proper riparian uses. One who has ownership of all riparian lands on a stream cannot validly divert the waters to nonriparian land nor authorize such diversion by others. All that one purchasing his entire riparian rights would acquire would be a freedom from adverse action based on ownership of riparian lands. Authority for diversion must be held from the state as the trustee for the public in ownership of the stream, before a diversion can be considered fully authorized. However, such state authorization for diversion does not carry with it any divestment of riparian rights which might be invaded by the diversion. One acquiring such diversion authority from a state may still be called upon to acquire the riparian property rights of those downstream from the point of diversion. Most public water supply agencies have or may secure from their states the right to divert water from streams. Such an agency, it must be emphasized, does not acquire diversion rights merely by ownership of riparian land. Diversion is not a riparian right.

The riparian rights affected may be acquired by purchase; by open, notorious and adverse possession for a length of time sufficient under state law to vest title by adverse possession; or by the exercise of the right of eminent domain if the diverter be empowered by the state to take private property for a public use upon making just compensation. Most public water supply agencies are so empowered.

Diversion Requires Riparian Rights Release

Where a public water supply agency, duly authorized to divert, fails to secure release of or to acquire the affected riparian rights the owners of such rights may apply for an injunction to restrain the diversion. Here, if the public interest would be adversely affected by having the diversion restrained, the courts customarily refuse the injunction on condition that the property rights be legally acquired or permanent damages be paid. Public interest will take precedence over private inconvenience if constitutional requirements of protection to private property be observed.

It has been stated above that the mere ownership of riparian lands does not vest in a public water supply agency the right to divert water from the stream. A properly authorized agency is in a much stronger position than a mere riparian owner. If holding authority from the state it may divert water—a riparian owner has no such right. The agency is performing a service to the public and upper riparian owners may well be subject to police power regulations regarding contamination of the stream by uses on riparian lands which regulations would not apply if merely private riparian owners' rights were involved. A use on riparian lands might be held to be a restrainable public nuisance if it endangered a public water supply but, at most, a private nuisance if only a riparian right were involved.

Sewage Works and Streams

The legal principles concerning private rights in streams stated above under Water Works and Streams are equally applicable here. However, where public water supply agencies may draw their supplies from a stream a public sewage agency may use a stream as the means of carrying away its sewage system effluent. In one case it is the beginning of the system and in the other, the end of the system.

As with public water supply agencies, public sewage agencies perform a public function. They are created to perform this function and are endowed with the powers deemed essential to its performance. From the provisions of some statutes dealing with the creation and powers of sewage agencies it would seem that the lawmakers believed that many powers were essential which would not be so considered in the light of present day knowledge of the science and arts of sewage disposal. While it is true that most systems require an ultimate discharge into a stream, it does not appear today that such discharge need create a public or even a private nuisance. Yet statutes have been found specifically exempting sewage agencies from all liability for public or private nuisances resulting from discharge of sewage into streams. There are cases in the books refusing any relief to property owners whose property value had admittedly been destroyed by the discharge of sewage on their lands. In these days of modern sewage disposal plants, similar facts would result in very different decisions. Sewage must be discharged and private rights may be subject to public necessity but when the necessity vanishes private rights become controlling.

Sewage Agencies Also Subject To Riparian Rights

Since under the law of riparian rights the owners have a property interest in having their stream reach their land unimpaired in quality except such impairment as results from natural or reasnable artificial uses on upstream riparian lands; and since a city could not conceivably be a riparian owner as to all the property served by its sewage system; and since an artificial use which destroyed the usefulness of a stream could hardly be considered a reasonable use; it seems, on principle, that a city which invades the property rights of owners downstream from its sewer point of discharge should make adequate compensation for the taking of property or for its damages.

With the possibility of modern disposal plants it would seem that an injunction might be issued by the courts, requiring either the prompt eradication of the objectionable conditions by the placing in operation of an adequate treatment plant or the acquisition of the affected property or property right. In case of a true public nuisance spreading beyond riparian owners in its effects, it would seem that the modern plants would be the only solution.

A direct conflict of interest develops when a public sewage agency's dis-

charge contaminates a public water supply agency's soure of supply. Here there is a public nuisance in which no person or entity can have a property right and a situation calling for the application promptly of strong police power measures. Here the public interest in a pure water supply is the controlling factor—not the riparian rights of the water supply agency.

Occupancy or Use of Private Property

In addition to invasion of private rights in streams which have been considered above, both water and sewage agencies at times find themselves involved in situations where it seems essential for them to occupy or use private property. Consider first the matter of water facilities or sewers in streets or roads. In most jurisdictions the owners of property abutting on a public street or road own the land occupied by it subject to the public's rights to travel over it. In built up sections the general rule is that the use of the subsurface of streets and roads by such facilities as water lines and sewers does not constitute an invasion of the property of the abutting owners. Complications develop, however, when a street or road is legally closed and the right of travel ceases. The abutting owners usually take clear title to the street or road, surface and subsurface, and unless some legal provision be made to maintain the subsurface facilities in place, difficulties may arise. Under the common law the situation is different in truly rural areas. In such areas the abutting property owner holds title to the bed of the road subject only to the right of public travel. Thus water lines and sewers in such roads are in priate property. Property owners usually are content as such facilities available for use add to the value of their property.

Lines and other facilities of agencies on private property outside of streets, alleys, lanes or roads are laid or maintained in violation of private property rights unless by some means rights be acquired. It must be remembered that before a right can be obtained by adverse possession the possession must be adverse, open and notorious for the requisite length of time. Since water lines and sewers are usually buried under ground there is no open and notorious possession of the land by them unless there be surface indications of their presence in the land or other evidence of knowledge of the occupancy by the owner of the land.

Water and Sewage Agencies Liability for Damages

At the outset it can be stated that both water supply and sewage agencies, whether publicly or privately owned, are engaged in the performance of a public function. However, privately owned agencies obviously are not engaged in a governmental function and it has been held that when a governmental unit or public authority offers water or sewer service it acts in a proprietary and not a governmental capacity. The language of the opinions in different cases seem often to present conflicting reasoning and even confusion of thought. However, the authorities seem to be in agreement that for damages due to faults in construction, operation or maintenance of either water works or sewage systems the publicly owned systems are liable, just as a private corporation would be liable.

The one exception seems to be fire losses. Fire fighting or fire protection is a governmental function and there cannot be liability for failure in performance of a governmental function. Thus, with this one exception, both publicly and privately owned water and sewage agencies are liable for damages due to officers' or agents' neglect or failure to act as reasonable prudent men would act under the circumstances.

It is very difficult to make a brief statement of even the bare essentials of the basis of damage claims based on negligence. For the purposes of this paper such a brief statement is here presented with the understanding that it could—or should—be supplemented with qualifications or conditions.

Before there is a legal liability for damages in negligence cases seven elements must be present. These seven elements are:

1. Damages must have been suffered by some person.
2. This person must be one to whom the actor owes a duty of protection or assistance.
3. The actor must have done or failed to do some act.
4. The action or failure to act must have caused the damage.
5. The action or failure to act must have involved an unreasonable risk to others.
6. The action or failure to act must not have measured up to the standard of good practice under the circumstances.
7. The failure to act must have been a failure to act in a way in which the actor was under a duty to act.

Examples of Liability

Some comments on some of these elements and some illustrative applications of the principles are in order. Consider first the second element stated above. Water works operators are understandably concerned about drownings in reservoirs. These most often occur in distribution reservoirs which are closed to the public, and usually protected by fences. If the public be forbidden access to the resservoir, then anyone reaching or entering it is a trespasser. The water supply agency does not owe a trespasser a duty of protecting him from drowning. In a drowning case involving only these facts there is no liability. As an aside—the "attractive nuisance" principle has been held inapplicable to such cases.

Turn now to the sixth element—standard of good practice. The standard of good practice is the practice of a reasonable man under the circumstances. This standard, for the purposes of the present discussion, is the practice of properly trained water or sewage works men. If a water or sewage works man acts or fails to act in the way a properly trained man in his position would act, then his conduct does not meet the standard of good practice.

Turn now to number five element —unreasonable risk to others. An unreasonable risk is one where the utility of the act is outweighed by the dangers involved. Certainly placing water under pressure in city streets involves the risk that it may escape and flood basements and wreck buildings. The utility of the act of so placing the water lies in the fact that the inhabitants of the community are furnished a service essential to urban life. The act of placing the water in the streets—if done under proper conditions—does not involve an unreasonable risk to others.

A few illustrative applications will be considered. Public water supply agencies are held liable in damages for injuries due to water main breaks if the injuries were caused by negligence on the part of agents of the agency. As has been seen, the placing of the main in the street was not conduct involving an unreasonable risk to others but if those in charge of such placing used methods or materials which were not up to good water works practice and such improper methods or materials resulted in the break, then there was negligence and

liability. A duty was owed to those injured—the duty exercising proper care in installing and maintaining facilities for service. The failure to install the main properly or rather the act of improperly installing the main, was conduct which involved an unreasonable risk of harm to others. When a break occurs—without negligence—but the water is not cut off as promptly as good water works practice would indicate as proper, there is negligence in operation and liability. Liability depends on negligence. The same principles apply to damage claims arising from broken or clogged sewer mains.

A public water supply agency renders itself liable for damages resulting from furnishing water dangerous to health if negligence be involved. Here the standards of good conduct against which the conduct in question is to be measured are very high. Public health depends upon a safe public water supply and conduct which imperils such a supply does not measure up to proper standards. Those standards have been greatly raised in the last fifty years and will probably continue to be raised. Cases decided before and as late as 1900 reveal water works conduct which would today be considered grossly hazardous to public health being at the time considered non-negligent. With advancing knowledge of the causes and spread of diseases and advancing knowledge of water purification methods and of means of protecting the safety of water in a system, courts will be increasingly critical of water works conduct resulting in contamination of water furnished consumers.

In general, the thought is that a public water supply agency should be held as warranting the safety of the water which it furnishes its customers. A food seller, or a boarding house is held liable if it furnishes food dangerous to health even though no negligence be present because it is presumed to warrant that the food is safe for human consumption. The claim has been advanced that even though no negligence be present, the public water supply agency should be liable for furnishing unsafe water because it should be assumed to have warranted its safety. It is said that consumers have no way of knowing whether the water they take from a public supply is safe but must, of necessity, rely on the public agency which supplies it. No case has been found where that claim of warranty has been finally sustained. Good water works men can make sure that the water delivered to the distribution system is safe and can make reasonably sure that it remains so throughout the distribution system up to the customer's premises. No way has been devised by even the best and most wealthy systems to prevent contamination within the customer's premises through back syphonage traceable to improper use of proper plumbing facilities. Thus there would be no justice in holding the agency as warranting the safety of the water at the point it is consumed. Yet it is at that point, and only there, that the warranty if it existed could have value.

Claims for Fire Losses

Some comments should be offered concerning claims against public water supply agencies for five losses. As has been indicated above municipally owned water supply agencies are held to be acting in a governmental capacity when they supply water for fire fighting. Acting in that capacity they are not subject to liability for failures in performance. Privately owned agencies do not have this out. However, such agencies furnish service for public fire protection under contract with the municipalities and the courts (except in Kentucky, North Carolina and Florida) hold that property owners who suffer fire losses are not privy to such contracts and have no right to sue the agency for breach of contract. They hold further that the agency owes no duty to the property owner to protect his property with the result that failure to protect is not a breach of a duty. Under the second element essential to liability for tort as stated above there is no liability even for failure to take proper steps. The cases indicate, however, that the agency does owe a duty to the property owner not to do positive acts which cause the damage. Actually shutting off a water supply during a fire would be an instance of such an act. This is distinguished from a failure to act such as failing to install mains of adequate size for fire fighting service. The three states Kentucky, North Carolina and Florida hold that the property owners are beneficiaries under the contracts and entitled to sue for breach. However, they require proof of negligence.

Fire Service Contracts

Obviously the wording of the fire service contracts becomes important. If an agency agreed to protect all premises in case of fire and made the property owners third party beneficiaries under the contract, the agency would be liable in case of breach of such contract. All that fire service contracts customarily provide is that the public representatives, in case of fire, may draw water through company facilities to fight the fire. At most they fix a minimum pressure to be maintained at one or more critical points in the system. This writer has never seen a contract for public fire service in which the company undertook to, or represented that its facilities were adequate to, extinguish fires at all points or even at any particular point. There is, then, no such holding out or representing, as would justify a court in finding liability on the basis of an implied warranty. Companies are subject to regulation and if fire service be in fact inadequate its strengthening may be compelled if the municipality be ready to assume payment for the increased cost of such service.

It should not be lost from sight that many circumstances lead to a fire loss. Some act or omission or some occurence entirely independent of the water company first starts the fire. Next there are the circumstances of structure, contents, and weather which may control the rapidity of spread. Next there are circumstances relating to the timing of calling for adequate help and of the arrival of such help. Next there are the circumstances of the adequacy of fire department equipment and the skill, courage and devotion of fire company personnel. At what point in time and in loss would even a clear case of negligence in water works operation become the proximate cause of the loss? In such a complicated situation the courts are on strong ground—socially—in keeping the loss as one to be covered by insurance and carried by insurance companies whose legitimate business it is. Their charges are based on the value of the property covered. On the other hand, water company fire service rates have no relation to the value of the properties of customers.

Conclusion

This article falls far short of covering the field of even the general legal principles applicable to water and sewage works. It is offered as a suggestive and—it is hoped—a helpful introduction to interesting and important studies, that should be pursued by those needing more exact information on the legalistic aspects of water and sewage operation and management.

Fifty Basic Safety Rules

The Safe Way, A Guide to Safe Working Practices*

published by **Jack & Heintz, Inc.**, Cleveland, Ohio

COMPANY PREMISES

1. Walk—do not run. There is much safety wisdom in this simple phrase. Another way of saying it—"Unnecessary haste may cause an accident."

2. Use designated entrances when entering or leaving the plants.

3. If you are operating a vehicle on the premises, never exceed 10 miles per hour. When approaching corners or curves, slow down and sound a warning. The pedestrian has the right-of-way at all times.

4. Never engage in fighting or horseplay. Such action invariably leads to ill feeling and injury to self and others. Disciplinary action up to and including discharge may result from such activity.

5. Signs are posted to protect you. Comply with them.

6. Do not distract the attention of fellow workers. To do so may cause injury to a worker, poor workmanship in a product or damage to Company property.

7. Salt tablet dispensers are located throughout the plant. Take these tablets to combat heat fatigue.

FIRE

8. Learn the location of all exits, fire extinguishers, stretchers, first aid equipment, etc., in your area.

9. In the event smoke or fire is noticed, contact your Supervisor at one. If he is not available, call the telephone operator or, after 5:30 P.M. the Guardhouse, Ext. 240 at Plant 5, Plant 4 or Plant 1.

10. Do not go to the scene of a fire unless you are authorized to do so.

11. Never use water on any type of fire. Use the extinguishers. Before using the extinguisher, however, read the instructions on the label.

a. For all electrical fires, use carbon tetrachloride extinguishers, or other special ones provided for such fires.

b. For fires in inflammable liquids use foam-type or other special extinguishers.

c. For common fires such as rubbish, paper, wood, rags, etc., use soda-acid extinguishers.

12. Observe the No Smoking signs where posted.

ILLNESS, INJURY, INCAPABILITY

13. In the case of personal injury or illness, report to your Supervisor at once. He will send you to the Dispensary. All scratches, bruises, cuts—or any other injuries no matter how slight—should be given prompt medical attention. Never attempt to treat your own or your fellow worker's injuries. Play safe, let the trained medical personnel care for the injury.

14. No employee under the influence of intoxicants or drugs is a capable worker. He endangers the safety of everyone. He must not report to work under these conditions. Possession or use of intoxicants or drugs on Company premises will not be tolerated.

GOOD HOUSEKEEPING

15. Keep your machine and work area clean. Put wiping cloths, rubbish, papers and other refuse in the proper containers provided for this purpose.

16. Never spit in drinking fountains or on the floor. Such conduct is against all rules of cleanliness and health care.

17. Aisles, exits, fire extinguishers, alarm boxes, power panels or stretchers must never be blocked with skids, boxes, crates, racks, materials or equipment of any type. Always observe the yellow aisle markers.

WEARING APPAREL

18. Finger rings, bracelets, key chains or other articles of this nature can lead to serious injury when you're handling materials or operating machinery. Don't wear them on the job.

19. Gloves or gauntlets should never be worn when operating machinery unless their use has been specifically called for by the Supervisor.

20. Loose clothing is choice prey for moving machinery. Roll up your sleeves, don't wear flowing neckties—give the machinery nothing to grab at.

21. Wear good sturdy shoes—not tennis shoes, sandals or other such footwear. You'll not only protect yourself against falling objects or possible stubbing, but you'll be doing your feet a favor—good shoes are a rule of good foot health.

PROTECTIVE EQUIPMENT

22. Safety equipment, protective apparel, goggles, face shields, etc., are furnished by the Company for your protection and must be worn as specified by the Supervisor. Never underestimate this equipment's value to you—remember the case of Peter Aaron.

MATERIALS HANDLING

23. Do not attempt to lift or push objects which may be too heavy for you. See your Supervisor when you need help. Learn the right way of lifting to avoid serious strains. Bend your knees—keep your body erect—then push upward with your legs. It's much easier and safer this way.

24. If you're stacking steels or other material, always make the stacks square and even and make the ends of the stack parallel with the aisle. Remember: vibration can cause an improperly stacked pile to fall and perhaps cause serious injury to a passer by.

25. Do not climb on or over steel piles, dies or any stacks unless it is absolutely necessary to do so.

LADDERS AND SCAFFOLDS

26. If your work requires the use of a ladder, be certain that it is free from cracks, broken rungs or other defects.
27. Where there is the possibility of the ladder slipping, make certain that your ladder is equipped with safety spikes or shoes. As an added precaution, have a fellow workman hold the bottom of the ladder.
28. Never use makeshift, defective scaffolds, rigging or stages.

CHEMICALS, PAINTS AND SOLVENTS

29. All containers—acetylene gas and oxygen tanks, acid carboys, bottles, carbide cans, cyanide drums, chromic acid cans—must be safely stored and labeled according to their contents. Labels should indicate the particular danger—poison, explosion, fire, etc. Such materials must positively be handled and stored as directed by the Supervisor.
30. Never use thinner, naphtha or other combustibles to clean or remove spots from clothing.
31. All thinner, naphtha, gasoline and other combusibles must be stored in closed containers.
32. Rags with tacking varnish, paint thinner or other combustibles must be stored under water.
33. Naphtha, gasoline or any other inflammable liquids should never be poured in sewers or drains.
34. Approved safety goggles must be worn when handling acids and caustics or when working at or near any receptacles, tanks, etc., containing acids.
35. Approved face shields are provided and must be worn when pouring acid.
36. Know the location of all eye wash fountains and safety showers in your area.
37. No smoking, lighted matches or open flame is permitted in the vicinity of acids.

GAS CYLINDERS

38. All oxygen and acetylene cylinders, whether full or empty, must be handled and stored in an upright position. Keep full and empty cylinders separated. Never place cylinders near steam pipes, etc., or expose them to the direct rays of the sun. Securely fasten all cylinders in the upright position.
39. Use proper handling equipment when moving any cylinders, full or empty. Do not transport in a horizontal position or use the "barrel rolling" method. Cylinders must be in an upright position and capped when being transported, unless they are on an approved welding or cutting cart.
40. Never drop or handle cylinders in a rough manner. Never use cylinders as rollers or supports. They are to be used as gas containers only.
41. Cylinders must not be placed where there is any danger that they might be struck by a passing truck or falling objects.
42. Keep oxygen cylinders away from grease and oil. Never handle cylinders if your hands or gloves are greasy or oily. Oxygen under pressure is very dangerous and highly explosive if it comes in contact with oils or greases. Oxygen must never be used to "pre-charge" or "pressure-test" any device or vessel.
43. Use soapy water to test for cylinder leaks. Never use an open flame. Any leaky cylinders should be taken to the open air and the Supervisor should be notified of the condition immediately.

OPERATING MACHINERY

44. Do not operate any machinery or equipment unless you have been authorized to do so and have had proper instructions.
45. Guards or coverings must not be removed or disturbed except for the purpose of oiling, adjusting, inspecting or repairing machinery. If removed, this safety equipment must be replaced and securely fastened as soon as work has been completed.
46. Never tamper with electrical equipment. Never open an electrical switch box or enclosure.
47. Riding on electric or gasoline trucks by anyone other than the operator is not allowed except in cases where it is necessary to hold materials transit. Riders must have the approval of a Supervisor.

DEFECTIVE TOOLS

48. Never use defective hammers, punches, wrenches or other tools. Flying chips from mushroomed or split heads may cause injuries. Exchange defective tools or see that they are repaired.
49. Never strike together materials of equal hardness such as dies, jigs, fixtures, hammers, chisels, punches, etc.

COMPRESSED AIR

50. Never play with compressed air. Don't turn it onto yourself or anyone else. This air under pressure may enter the body and cause serious injury or death.

FUNCTIONAL OPERATIONS

IN THE FIELD of sanitary engineering, there are several operations which are fundamentally the same for water, sewage, or industrial waste treatment works. These operations, which may be termed functional, include: Pumping, Electricity, Flow Measurement, Instrumentation and Control, Chemical Handling and Feeding, Coagulation and Sedimentation, Corrosion Control, Laboratory Control, and Maintenance.

Pumping

Liquid will move from one point to a lower point under the influence of gravity, but will not move in the reverse direction without energy being expended to move it. Gravity flow is utilized in sewers and in some water distribution systems, but in most water works, pumps are required to provide the pressure necessary to deliver the water to the consumer's tap.

In sewage works, pump lift sewage from one sewer to a higher one, or from an interceptor to a treatment plant at a higher elevation. Pumps are also used to lift water from wells and to pump air, chemical solutions, sludge, gas, etc. The design of a pump will depend on the material to be handled, suction lift, discharge head, operating conditions and efficiency desired.

Electrical Equipment Operation

Today, most pumps are operated by electrical motors. Electricity also operates instruments, controls, signals, communications, chemical feeders, and lighting systems. Electricity, and its potentialities and properties, is necessary to the operation of any water, sewage or waste treatment facility. Equally important are electrical motors which operate pumps and other equipment.

Flow Measurement

Where volumes of liquids or other substances are moved from one point to another, it is desirable to know, not to guess, the quantity of material handled. Reasons for flow measurement include: To provide data and information on plant production; to provide information on operation efficiency; to control unit operations; to ascertain quantity of water sold or volume of sewage treated; to determine costs of operation; and to provide permanent records of operation.

Points of flow measurement should be set up wherever measurement of volume in motion will produce information to satisfy any of the reasons for flow measurement. The more completely metered a water or sewage plant, the better and more efficiently it can be operated.

Instrumentation and Control

Instruments, sometimes called receivers or secondary instruments, are devices which indicate, record or totalize some function of operation which is being measured. Flow, levels, pressure, loss of head, temperature, etc., are conditions of operation which may be shown or recorded on a secondary instrument. Indicators show conditions at the moment of observations, recorders give a permanent and continuous record on a chart showing conditions as they existed at any moment. Totalizers give a numerical summation, to the moment of observation, of quantities in motion.

Closely coupled with instrumentation is the matter of control. Control of flow, control of chemical feeding dosage, control of filter operations, control of treatment operations are all essential to proper operation of water, sewage or waste treatment facility. Control can be obtained by the use of devices which operate in conjunction with or in direct response to flow measuring devices and their secondary instruments or in conjunction with other operating devices and instruments. The high cost and weaknesses of manual operating procedures can be greatly reduced by the use of instrumentation and control.

Chemical Handling and Feeding

Whenever water, sewage or wastes require chemical treatment of any kind, the plant operator is faced with the problems of handling and storage of chemicals, and with adding the proper amounts of chemicals to produce the treatment desired.

Chemical handling begins with the receipt of a shipment of chemicals and ends with the introduction of the chemical into a chemical feeder. Chemical feeding involves the operation of a device to add controlled amounts of the chemical to definite volumes of liquid. Control of chemical dosage according to the needs of treatment and flow to be treated is accomplished by chemical feeders designed for the purpose and controlled by a flow measuring device, or manually. Different types of chemical feeders are designed to feed solids, liquids or solutions, and gases. The selection of chemical feeders depends on a study of type of installation, treatment required, chemical used, dosage range, control, etc.

Coagulation and Sedimentation

Removal of suspended solids is necessary in surface water supplies, water softening operations. This operation involves sedimentation, which may take place in rectangular or circular tanks, usually equipped with mechanical devices for the removal of the settled material.

Design of sedimentation tanks is related to rate of flow, rate of settling of particles, detention times and facilities for removal of solids. Operation is controlled according to loading, both as to liquid and solid volume.

When solids in a liquid are too fine to settle easily by themselves (i.e., bacteria, colloids, etc.), chemicals may be added to create flocs which will settle and sweep out the fine particles. Coagulation is controled by analysis of the liquid and the proper dosage of the coagulating chemicals.

Corrosion Control

Since water is almost a universal solvent, its presence creates the problem of corrosion. Under certain conditions almost all metals will corrode or be attacked, as will concrete. In many cases corrosion may become a serious problem in water or sewage works. It can be controlled or prevented in various ways. The control may involve protective coatings, or chemical treatment of the liquid to reduce its corosive properties.

Laboratory Control and Maintenance

While the actual laboratory tests made in water plants may differ from those in a sewage works, the fundamentals of analytical chemistry and bacteriology are used in the operation of a control laboratory. Laboratory control can improve plant operations and the quality of the effluent, and often reduce costs of operation.

Maintenance, particularly preventive maintenance, reduces operating costs, improves efficiency and lengthens the life of equipment.

Centrifugal Pump Efficiencies

by H. E. BECKWITH
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WITHIN the past third of a century the slow-moving steam-driven piston pump has largely been displaced in the water works industry by the motor- or turbine-driven centrifugal pump.

This minor revolution has brought new problems for the operator because, unlike displacement pumps, centrifugal pumps are designed to operate under rigidly fixed conditions. Any appreciable variation from these fixed conditions will result in a decrease in efficiency. Just because a centrifugal pump will pump water does not constitute proof that it is doing a satisfactory job. It not only should pump water, but it also should do it with the maximum possible efficiency. Some elementary knowledge of how a centrifugal pump operates may be helpful in understanding how this may be achieved.

At some time in his life every boy ties a horse chestnut, or similar object to the end of a string. By whirling it about his head he builds up enough velocity to send the chestnut soaring into the air when the string is released. The principle of building up velocity in that chestnut by whirling is the same principle used in the design of a centrifugal pump. The water enters the pump through the suction inlet, is seized by the vanes of the impeller, and spun until it is rotating at terrific velocity.

Since pressure and not velocity is chiefly desired, the pump is so designed that by gradually slowing down this velocity in the casing, the energy stored in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The velocity, and therefore the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the radius of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter, so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage." As electrically-driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from the condition will result in decreased efficiency.

Typical Performance Curves

Figure 1 is a typical centrifugal pump curve, used for illustration during the discussion. Similar curves are available from the manufacturer for all medium-sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75 percent) is secured when the head is about 155 ft and the discharge rate is about 1,300 gpm. Also, as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in the effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies under a wider range of operating conditions.

Proper Head A Must

It is highly important when selecting a pump to be certain that the head is properly chosen. It is not accurate to take the difference in elevation between the clearwell and the reservoir or tank into which the water is pumped as the total pumping head. To this must be added friction losses, and in the instance of very low-head pumps there must also be added velocity head. To illustrate how important this friction head can be, if we have figured on the pump whose curve is given in Figure 1, and if we are pumping through two miles of 16 in. main, the friction loss will add about 18 ft. to the pumping head, making it 173 ft. At this head (see Fig. 1) the pumping rate will drop to 1,000 gpm and the efficiency to 70 percent.

Furthermore, the pump is operating on a very critical part of the curve, where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would cause a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump after installation when the pumping head has been increased above the head for which it was designed. As it is the nature of unlined iron and steel mains to tuberculate, with a constantly rising friction loss, this is an important consideration.

This can be illustrated in another way. Suppose that we are in the market for a 1,000-gpm pump operating against a total head of 173 ft, and the pump whose curve we have been using has been submitted for consideration—it might be. This pump would not be considered a good "buy" to operate under these conditions. In the

Ed. Note: Some years ago, Mr. Beckwith wrote an article on centrifugal pumps, their selection and checking. That article was published in several editions of the Reference & Data Number of Water & Sewage Works. At the request of the editors, Mr. Beckwith has revised and brought the article up to date.

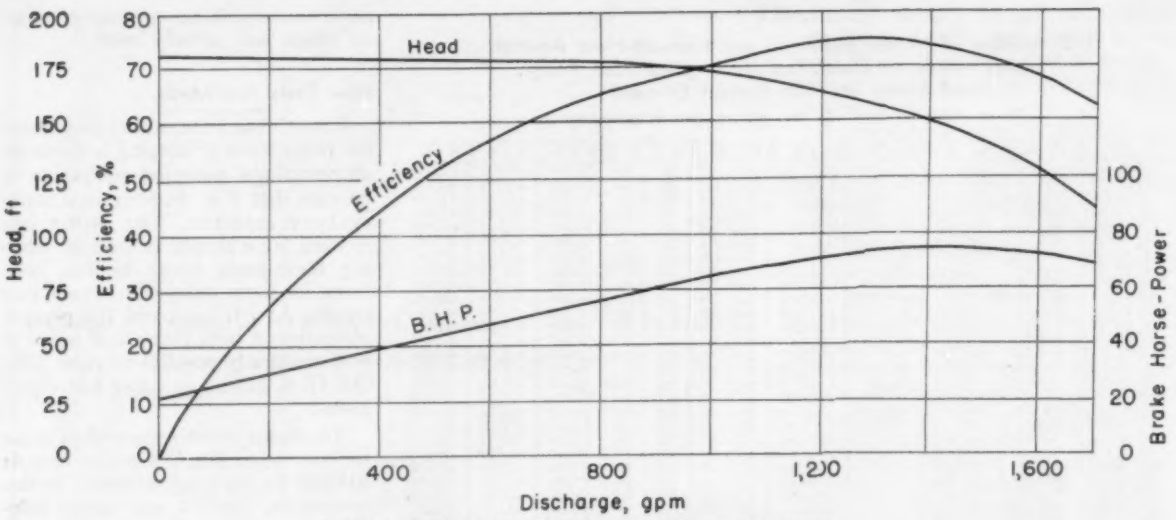


Fig. 1—TYPICAL centrifugal pump performance curves.

first place, it will be noted that the efficiency of 70 percent is much below the maximum efficiency of 75 percent.

But even more important, perhaps, is the fact that the pump at 173 ft head is operating under critical head conditions. An increase of only about 8 ft (or less than 5 percent) in the pumping head would bring the head to the maximum which the pump can create—in other words, to the "cut off" point. This means that an increase in the head of only 8 ft (about 3½ lb) would decrease the pumping rate from 1,000 gpm to 0 gpm. Moreover, an increase of only 3 ft in head would cause a drop of 200 gpm in the pumping rate.

On the other hand, when working in the most efficient range of the pump a change of 3 ft in the head would only cause a variation of 30 to 40 gpm in the pumping rate, and the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning is not amiss. By making the vertical scale of the curve less than is customary, a much flatter *appearing* efficiency curve can be secured. Therefore, in comparing the performance curves of pumps one should be sure that they are plotted on comparable scales. The author has known curves with reduced vertical scales to be submitted where he felt sure that the scale was deliberately reduced for the purpose of deception.

More Flow, But Less Efficiency

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 gpm against 155 ft head it should have less trouble pumping the same amount from the river to the settling basin against a head of only 40 or 50 ft. This is so. In fact, the curve shows that it will pump much more than 1,300 gpm at the lower head. The curve does not go out that far, but it goes far enough to show what would happen, not only to the pumping rate but to the efficiency as well. The pumping rate goes up, but the efficiency goes down—yes, way down.

Reducing the head has a tendency to cause a pump to "run away," much as an automobile would run away down hill, when the going becomes easier, if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, the head is often artificially increased by closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly, as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. Installations such as this are known where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor.

But it is not always necessary to buy a new pump just because the head has been reduced. The pressure generated by a constant-speed centrifugal pump can be cut down by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise how much will have to be machined off the outside of the present impeller so that it will pump efficiently; or at a slight expense he will furnish a new impeller for the changed conditions.

It is sometimes, but not always, possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded.

If the revolutions of any centrifugal pump are increased the head which that pump will generate will be increased. This explains why a certain pump gave a wire-to-water efficiency of only 40 percent. This pump was designed for use with a gasoline motor and to operate under the existing head conditions at a speed of 1,400 rpm. Eventually electric power became available, the pump was connected to an electric motor, and the speed was increased to 1,800 rpm. This, of course, increased the head generated by the pump itself, with the result that it was working against only a portion of its design head and the efficiency was, consequently, very low.

Some Odd Cases

A somewhat similar condition was found several years ago when a 4-mgd installation designed to work against a head of 100 lb was found to have been connected in series to a 5-mgd pump designed to pump against 50-lb pressure. This gave an installation with a design head of 150 lb, but the actual head was still about 100 lb. The output was thereby increased to approximately a 6-mgd, but the efficiency decreased to the point where it was only slightly above 40 percent. New and properly designed equipment brought the wire-to-water ef-

TABLE I

U.S. Gallons of Water Delivered per Kilowatt-Hour Against Various Heads on Theoretical Assumption That Pump and Motor are 100 Percent Efficient

H = head in feet. G = gallons per kilowatt-hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,007	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	861	408	780	458	695
9	35,360	59	5,934	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,974	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	222	1,434	275	1,171	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,260	74	4,301	126	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,788	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,858	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	132	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	8,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

ficiency up to about 75 percent.

It can be readily seen from the foregoing that the chances of buying a suitable pump from the junk man are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absolutely worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from junk dealers.

So far, the discussion has concerned equipment working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance could not be secured under these conditions.

However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time when a water snake was found wrapped around the shaft, with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15-ft maximum for best performance.

In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple-stage pump and the water was short-circuiting back from a higher stage to a lower stage. One engineer once reported that an efficiency of 20 percent was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps, but which were determined as the result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparently low efficiency was caused by this meter being set 20 percent high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water actually discharged into the system over a 24-hr period the pump had an efficiency of only 8 percent. Had a standpipe or reservior been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

How Tests Are Made

Enough has been said to emphasize the importance of keeping a check on all centrifugal pumping equipment to be sure that it is working in a satisfactory manner. The writer has worked out a simple method for making these tests which he has been using for some years with satisfactory results. At 1-ft head and 100 percent efficiency of both pump and motor it is theoretically possible to raise 318,200 U. S. gallons of water 1-ft with 1 kwh.

To determine this theoretical value for any other head, simply divide 318,200 by the head involved. In this connection Table 1 may prove helpful in reducing calculations in pump testing. For instance, the value at 159 ft would be $\frac{318,200}{159} = 2,002$ gal. per kwh. To determine the wire-to-water efficiency of an installation it is only necessary to divide the actual pumpage per kwh by the theoretical value for the pumping head, as previously determined. A rough check can be made by dividing the month's pumpage in gallons by the kwh consumed. This gives the gallons actually pumped per kwh.

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as shown) to determine the theoretical 100 percent pumpage per kwh. Next, divide the actual gallons per kwh by the theoretical gallons per kwh to secure the wire-to-water efficiency.

Example

Assume a monthly pumpage of 32.-64 mg and a monthly power consumption of 30,200 kwh. Say the total head noted was 220 ft. Dividing 32,640,000 by 30,200 gives an actual pumpage of 1,081 gal. per kwh. Dividing 318,200 by 220 gives a theoretical value of a possible 1,447 gal. per kwh at 100 percent efficiency.

$$\frac{1,081 \text{ (observer)}}{1,477 \text{ (theoretical)}} = 74.7\%$$

overall wire-to-water efficiency.

Second Method

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this

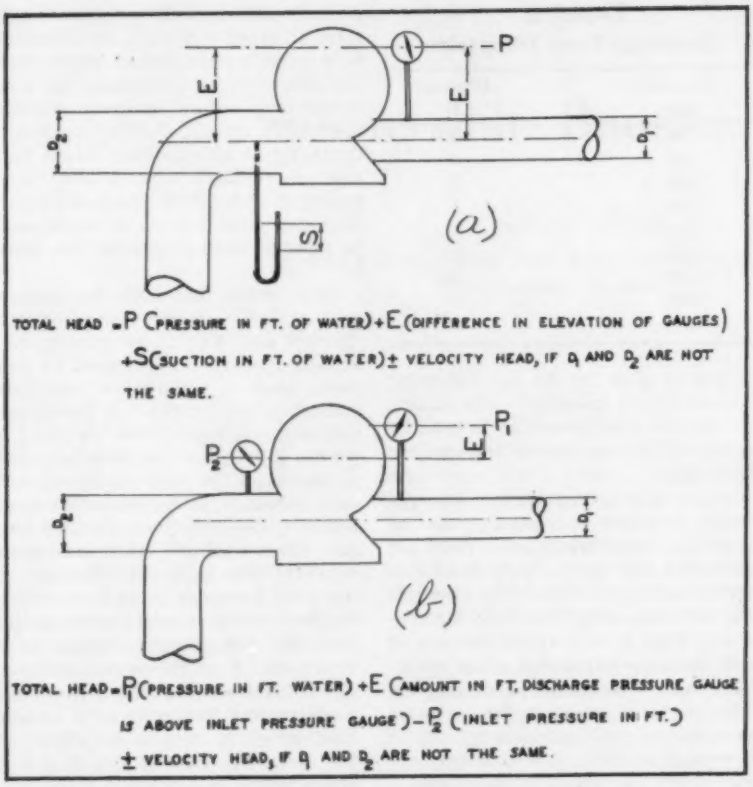

-P
E
E
D2
D1
S
(a)
TOTAL HEAD = P (PRESSURE IN FT. OF WATER) + E (DIFFERENCE IN ELEVATION OF GAUGES) + S (SUCTION IN FT. OF WATER) ± VELOCITY HEAD, IF D1 AND D2 ARE NOT THE SAME.
P2
P1
E
D2
D1
(b)
TOTAL HEAD = P1 (PRESSURE IN FT. WATER) + E (AMOUNT IN FT. DISCHARGE PRESSURE GAUGE IS ABOVE INLET PRESSURE GAUGE) - P2 (INLET PRESSURE IN FT.) ± VELOCITY HEAD, IF D1 AND D2 ARE NOT THE SAME.

Fig. 2—HEAD measurement with inlet pipe (a) under suction and (b) under pressure.

period measure the output of the pump with any suitable mainline meter. Keep a close record also of the discharge pressure and the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for 10 or 20 minutes the rate of power input can be closely ascertained. Or the power company may be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, this latter method is the only feasible one for testing each unit separately.

The total head in feet must first be secured. If the pressure gage reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31, the feet of head giving 1 lb of gage pressure. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gage and the point of suction measurement. The total head then becomes the sum of the discharge pressure, the suction, the vertical distance, the pressure gage is above the point of suction measurement, and the velocity head, all expressed in feet.

Velocity head generally may be ignored, as it is usually a small factor for the relatively high heads which normally exist in water works operation. However, if the diameter of the suction pipe at the point where the suction is measured varies from the diameter of the pipe at the point where the discharge pressure is measured, the velocity head at each point can be computed from the formula

$$H_{vel} = \frac{V^2}{2g}$$

The suction measurement includes the velocity head at the point of suction measurement, so that all that enters into the computation is the difference in diameter (if any) between the suction and discharge pipes at their respective points of measurement. Thus the velocity head usd in the computation is

$$H_{vel} = \frac{V_1^2}{64.32} - \frac{V_2^2}{64.32}$$

in which V_1 is the discharge velocity and V_2 is the suction velocity. If this quantity should be an appreciable amount it should be included in the total head. However, this is usually true only in the case of very low-head pumps.

A pressure reading is effective at the coil or center of the usual circular gage, whereas suction measurement is effective at the point where the connection is made to the suction pipe. This is because the pipe leading to the pressure gage is filled with water and the pipe leading to the suction gage is filled with weightless air. Of course, if the inlet pipe to the pump is under pressure its takeoff pipe is filled with water and the measurement is made to the center of the gage (see Fig. 2).

A word of caution may not be out of place at this point. The practical limit for suction under summer operating conditions is usually 15 ft. This includes not only the difference in elevation between the pump and the clear well, but also the loss at entrance, the friction loss, and the velocity head in the suction pipe. Therefore, care must be exercised not to set the pumps too far above the clear well or difficulties in operation, attended by low efficiencies, will result.

Computations

We can now proceed to the actual computations.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value for the head against which the pump worked. This gives the over-all wire-to-water efficiency of the installation.

As an example, assume an installation where the following test data were secured on a pump with 8 in. suction and 6 in. discharge:

Power input to motor	90.0	kw	
Rate of discharge	51,840	gph	
Delivery per kwh	572	gal	
Pressure	146	lb =	337 ft
Suction	15	in =	17 ft
Diff. in gage elev.	1	ft =	1 ft
Velocity head	1	ft =	1 ft
Total head			356 ft

The velocity head was determined in the following manner: The suction having been measured at the 8 in. suction flange and the pressure having been measured at the 6 in. discharge flange of the pump,

51,840 gph
= 864 gpm
= 9.75 fps velocity at 6 in. flange
= 5.50 fps velocity at 8 in. flange

Vel. head at discharge flange

$$= \frac{V_1^2}{64.32} = \frac{(9.75)^2}{64.32} = 1.44 \text{ ft.}$$

Vel. head at inlet flange

$$= \frac{V_s^2}{64.32} = \frac{(5.50)^2}{64.32} = 0.47 \text{ ft}$$

Difference ..... = 0.97 ft

Theoretical discharge at 356-ft Head (from table) .. = 894 gal. per kwh.

Over-all efficiency ... $= \frac{572}{894} = 64\%$

It will be noted that if velocity head had been ignored, the result would have been effected less than 0.3 per cent. If the suction and discharge head measurements had been taken on the 20 in. suction and 16 in. discharge mains, the velocity head would have been almost nothing.

If a suction gage is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gage, adding to this measured distance about 3 ft for loss in bends, velocity head, etc.

Having shown the desirability of frequent tests and a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following over-all (wire-to-water) efficiencies. It will be noted that the larger the pump, the higher the efficiencies (see Table 2).

TABLE 2
Centrifugal Pump Efficiencies

Capacity gpm	Efficiency %
200	62
400	65
600	68
800	71
1,000	73
1,500	75
3,000	80
5,000	82
5,000+	85

There will be variations from the values of Table 2, depending on the head and other conditions. They are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment now available that it is decidedly uneconomical to keep it in operation.

It will be worthwhile to check the present efficiency of equipment now more than ten years old, to determine how great a reduction in power consumption can be secured by the substitution of more efficient modern pumps. If an old 1,000-gpm pump, operating at an efficiency of 57 percent, is replaced with a new pump giving an over-all efficiency of 73 percent the same amount of water may be pumped with 22 percent less power.

This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22 percent. Such a reduction might be enough to pay for the new installation in about one year's time. In order to get the gallons per kwh to be expected at any head, for any efficiency, it is only necessary to determine the theoretical gallons per kwh for that head and then multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per kwh, the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important (if not more so) than is the total kwh consumption in determining the power bill.

Submersible Booster Pump

by R. C. KENMIR

Chief Engineer, Office of James M. Montgomery, Consulting Engineer
Pasadena, California

BOOSTER PUMPING stations in residential areas have always posed a design and construction problem to the water works engineer.

If a building is put up to house the pumps, it must be attractively designed and properly maintained to avoid public criticism; and, if operation of the equipment can be heard at night by the neighbors, the water superintendent can expect endless complaints. The problem can be especially difficult if the pumping units are fairly large or of a size to cause frequent start and stop operation.

The submersible motor pump unit offers a satisfactory way of eliminating much of the noise in booster pumping stations, although consideration must still be given to the noise produced by the transformers, starting equipment and pump control valves. Unless the station is quite large, transformer hum usually is not serious. Starting equipment for large units and especially for equipment operating on voltages in excess of 480 volts, is sometimes quite noisy. Some types of pump control valves using solenoids produce objectionable hum. Where the noise must be kept to an absolute minimum it is sometimes necessary to house all sound-producing components; and, if necessary, provide suitable insulation to deaden the sound.

Fig. 1 illustrates the usual method of installing submersible pumps as boosters. The pump and motor unit is set in a vertical section of pipe (usually referred to as the "barrel") with the pump and motor suspended from a flange which, in turn, is bolted to the flange on the barrel. The flanged joint is provided with a gasket and designed for the maximum pressure to which the barrel may be subjected. If desired, the pump discharge and discharge valves may be installed in a vault below ground.

Although the use of submersible motors ordinarily limits the type of pump to a vertical pump, some industrial installations have been made in which submersible motors have been used to drive horizontal pumps. During recent years there has been a decided trend in booster pumping toward the use of vertical turbines, driven by either submersible or conventional motors. However, this trend has been more pronounced in the western part of the United States than elsewhere. In considering the proper pump for any given application in booster pumping the advantages and disadvantages of the various types of pumps which might be used should be given careful consideration. Some of the advantages and disadvantages of vertical turbine pumps are outlined below.

ADVANTAGES OF TURBINE PUMPS:

(1) Vertical turbine pumps require no housing in mild climates although in very cold climates, housing or other

MAIN Booster Pumping Station, Foothill Municipal Water District, Pasadena, Calif.

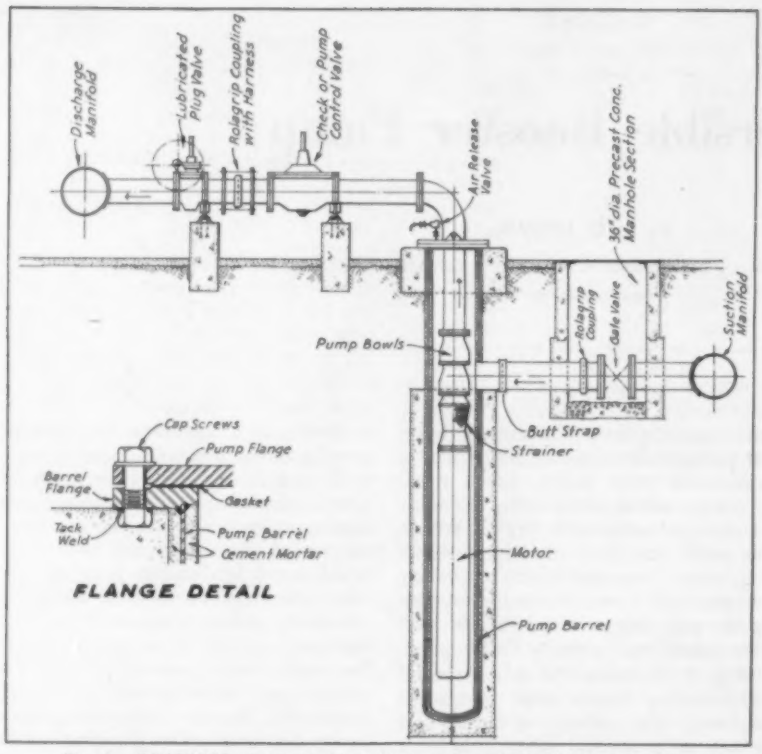


Fig. 1—DRAWING of a typical installation of a submersible booster pump.

protection may be needed to prevent freezing of the discharge piping. Conventional motors may require housing in order to muffle the sound of the motors.

(2) By setting the pump barrels for vertical turbines at the proper depth or by setting the pumps directly in a reservoir or sump, below-ground pump rooms or vaults can be avoided. Thus, with the motors set above ground, the danger of flooding from a break in the piping or from outside sources is eliminated.

(3) In some systems, the total head may fluctuate over a very wide range. Such a condition may be met easily with the vertical turbine without providing an excessively large motor. This is due to the relatively steep curve characteristic of the vertical turbine pump.

(4) The vertical turbine permits great flexibility in meeting changed head conditions. If at the time the pump is purchased, it is anticipated that head conditions may be increased in the future, the motor and shafting can be sized accordingly and later, additional bowl units added to meet the higher head condition. In the event a lower head condition is to be met, the bowl assembly may be simply destaged.

(5) A minimum amount of maintenance is required.

(6) A minimum amount of floor space is required.

DISADVANTAGES OF TURBINE PUMPS:

(1) The initial cost is greater than for either a vertical volute-type pump or a horizontal double suction pump.

(2) If housed, vertical turbines require considerable head room.

(3) Repairs to the pump are rather expensive, since the pump must be removed from the well or pit and usually must be sent to a repair shop.

In addition to the above advantages and disadvantages common to both conventional and submersible motor-driven turbine pumps, the submersible motor-driven unit has the following advantages and disadvantages.

ADVANTAGES OF SUBMERSIBLE PUMPS:

(1) Freedom from noise of any consequence.

(2) Protection against any kind of weather.

(3) Protection against tampering.

(4) Increased safety to both persons and mechanical equipment.

(5) Practically maintenance-free performance without need of adjustment or lubrication.

DISADVANTAGES OF SUBMERSIBLE PUMPS:

(1) Although efficiencies of the conventional vertical motor are usually comparable to those of the horizontal motor, the efficiency of the submersible motor is generally slightly lower than either type of conventional motor, due to the drag of the coolant within the motor. This difference, however, is of very little significance in the case of motors of under 100 hp.

(2) The submersible motor is more expensive than either the conventional vertical motor or the horizontal motor.

(3) Where submersibles are used for boosting, it is generally necessary to provide a relatively deep pump well or "barrel," due to the fact that the motor is attached to the pump below the bowl assembly and suction strainer of the pump.

(4) In the case of some submersibles, if any trouble develops within the motor it cannot be repaired in the ordinary motor shop but must be sent to the factory. However, some makes are of such design as to permit rewinding in local motor repair shops.

The following figures give some idea of the growing popularity of the submersible pump. One of the leading manufacturers of submersible pumps estimates that in 1956 between 60,000 and 70,000 submersibles were sold in the United States. This figure is broken down into the various sizes as follows:

⅓ to 5 hp	60,000
5 to 20 hp	2,000
20 to 75 hp	500
75 to 200 hp	250
200 to 500 hp	100

History of the Submersible Motor

Development of the submersible pump stems from the need to eliminate the inefficiency of conventional turbine pumps when installed in very deep wells. Pumps with settings several hundred feet below the ground have so many line shaft bearings there is a substantial loss in efficiency. The shaft (and tube in the case of oil lubricated units) represents an obstruction to flow which further reduces the efficiency of the conventional deep-well turbine. Some of the early designs were intended for use in oil wells and others were intended for use aboard ships.

The first patent on a submersible motor was issued in England to W. R. MacDonald in 1908 on a "wet-stator" type in which no attempt was made to exclude water from the windings. This design required heavy insulation on the individual conductors.

During the next two decades, there were many unsuccessful attempts made by both English and American manufacturers to develop a reliable submersible motor. Although some of the designs were very ingenious, most of them failed to prove the reliability required for practical applications. One of these was an "air-bell" type of English manufacture in which the housing was kept filled with air with the bottom of the housing open to the water. In 1921, a patent was issued to William Baum of Milwaukee, Wis, on a rather conventional appearing motor designed for underwater serv-

ice. The water was prevented from entering the motor by keeping the motor housing under the proper pressure with air supplied from an external source.

A rather ingenious English design consisted of a completely enclosed and sealed motor which drove the pump through two magnetic couplings separated by a thin diaphragm. One of the magnetic couplings was on the motor shaft sealed within the motor housing and the other was on the pump shaft in water. Water works men will recognize this drive as being similar to that now used on a popular propeller-type water meter in which the magnetic drive is located between the propeller and the sealed gearing. Another English design consisted of a conventional motor equipped with intricate mechanical seals.

It was not until the late 1920's that submersible motors were used to any great extent. The submersibles built during this period were of two types known as the "dry-stator" and the "oil-filled" types. The former was developed by Garvenswerke of Austria and the later by Reda Pump Company of Oklahoma and Submersible Pump Company of Los Angeles. The latter firm was taken over in 1936 by Byron Jackson Company. Several English and European manufacturers were marketing submersible motors of the "dry-stator" and "wet-stator" types prior to World War II.

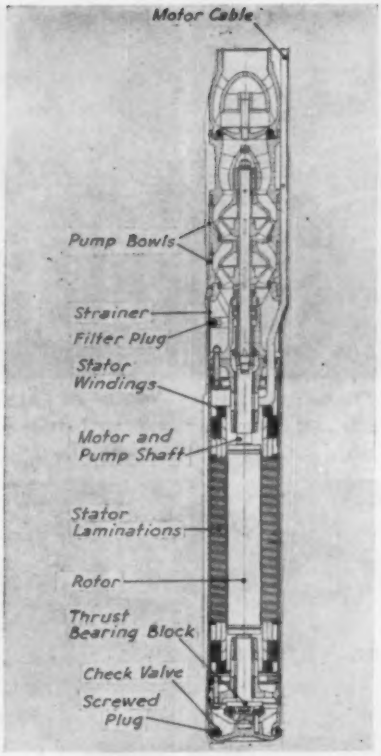


Fig. 3—SECTION of Pleuger Co's. submersible motor. (German-designed wet stator water-filled motor—1/3 to 550 hp.)

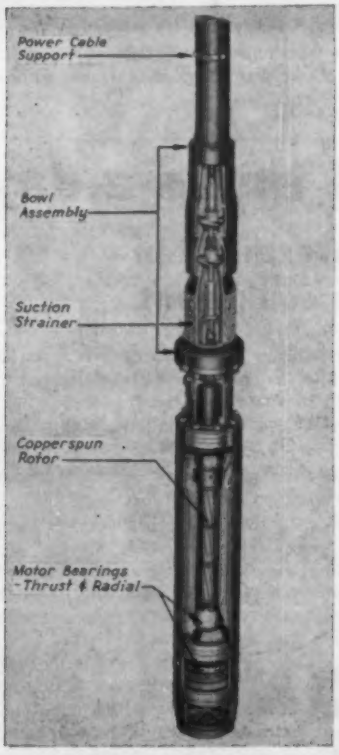


Fig. 2—SECTION of Fairbanks, Morse & Co's. submersible motor. (Wet stator water-filled motor with mechanical seal —15 to 200 hp.)

Types of Submersibles

The general characteristics of the various types of submersibles in current use are discussed in the following paragraphs.

Wet-Stator Types

In the wet-stator type, water is free to circulate throughout the motor. This requires all individual conductors to be insulated with either rubber or plastic. Although rubber was formerly used, the insulation now generally used is polyvinylchloride or polyethylene plastics. All parts in contact with the water, except the rotor and stator laminations, are usually made of non-corrosive materials. Due to the fact that non-corrosive materials do not have the magnetic properties required, carbon steel must be used for the rotor and stator laminations. Some manufacturers use special methods of treating the laminations so as to reduce the corrosive effect of the water. Proponents of oil-filled motors maintain that corrosion of the steel laminations, and in some waters, formation of scale in a wet-stator motor make this type of construction undesirable. However, manufacturers of the wet-stator motor point to their records of successful experience. Most manufacturers of the wet-stator motor recommend filling the motor with *clean* water and sealing the water in the motor, although some permit the motor to simply "soak up" water from the well or sump in which the pump is installed. "Sealing" in the water, as used with reference to wet-stator motors, is a relative term. Even with a mechanical seal, it is likely that there will be some interchange of water between the well or sump and the interior of the motor housing unless means are provided to take up the thermal expansion and contraction of the internal fluid. It is believed that the apparent lack of serious corrosion of the laminations in wet-stator motors can be attributed to the fact that once the small amount of oxygen in the water has been used up through the formation of corrosion products, there is no way for the oxygen to be replenished except from the small amount of interchange water which may enter motors of some de-

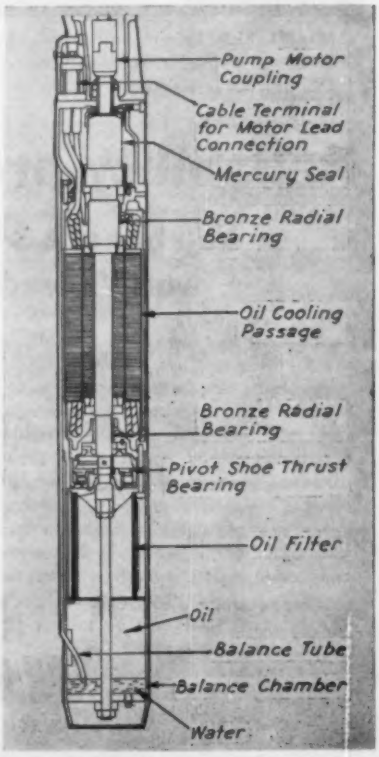
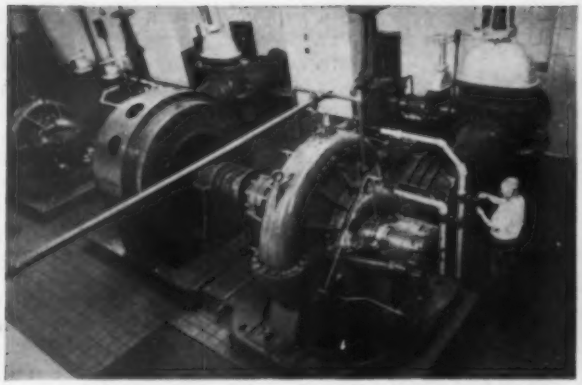
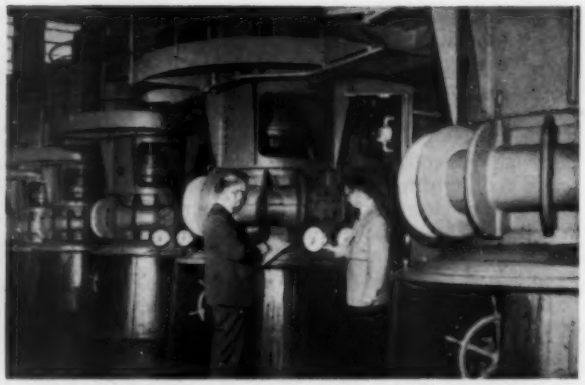


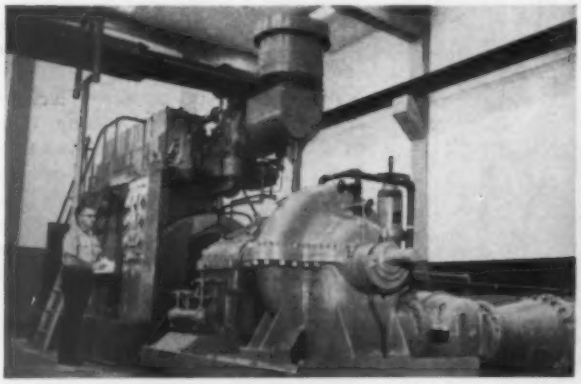
Fig. 4—SECTION of Byron-Jackson Co's. submersible motor. (Oil-filled motor with mercury seal—5 to 750 hp.)



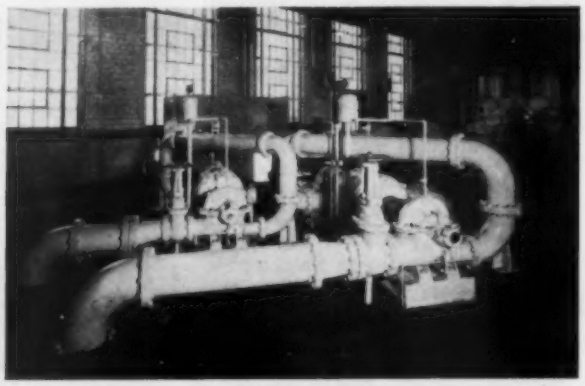
PHILADELPHIA, PA. One of ten Worthington high lift centrifugal pumps at the Torresdale Pumping Station. Capacity of this pump is 40 MGD.



NIAGARA FALLS, N. Y. Worthington high lift pumps in the Water Filtration Plant. In all, there are ten Worthington pumps, 15 to 30 MGD each.



MIAMI, FLA. One of four Worthington 15 MGD pumps driven by a Worthington diesel engine at the new Alexander Orr, Jr., Water Treatment Plant.



SHARON, PA. Two Worthington two-stage centrifugal pumps at the Sharon Valley Water Company. Capacity of the units is 2 MGD and 4 MGD each.

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TABLE 1

Manufacturers of Submersible Motors and Types Offered

Manufacturer	Location	Motor Horsepower	Type	Coolant	First Offering
AMERICAN MAKES					
Byron Jackson Pumps, Inc.	Los Angeles, Cal.	5—750	Open Winding	Oil	1928
Reda Pump Co.	Bartlesville, Okla.	⅓—300	Open Winding	Oil	1920*
Fairbanks, Morse & Co.	Beloit, Wis.	15—200	Wet Stator	Water	1950
General Electric Co. General Electric Co.	Fort Wayne, Ind. San Jose, Cal.	⅓—5 Up to 125	Plastic Impreg. Wind. Open Winding	Water & Glycol Oil	1953
U. S. Electrical Motors, inc. U. S. Electrical Motors, Inc.	Los Angeles, Cal. Los Angeles, Cal.	⅓—3 Up to 75	Plastic Impreg. Wind. Dry Stator	Water-oil Emul. Water & Glycol	1953
Pleuger Pump, Inc.	Lancaster, Pa.*	⅓—550	Wet Stator	Water	1929
Jacuzzi Bros., Inc.	Richmond, Cal.	1—25	Open Winding	Oil	1945*
Franklin Electric Co., Inc.	Bluffton, Ind.	⅓—20	Dry Stator	Water	1950
Jack and Heintz, Inc.	Cleveland, Ohio	⅓—3	Plastic Impreg. Wind. and Open Winding	Oil	1952
Sumo	Stamford, Conn.	⅓—60	Dry Stator	Water grease	1938
ENGLISH MAKES					
Beresford	England	½—170	Dry Stator	Water-oil Emul.	1951
Hayward-Tyler	England	3—450	Wet Stator	Water	1920
Sumo	England	⅓—60	Dry Stator	Water-grease	1938
EUROPEAN MAKES					
Klein, Schanzlin & Becker	Germany	½—1000	Wet Stator	Water	1930
Aturia	Italy	¾—7	Dry Stator	Water-oil Emul.	1940
Garvens	Austria	½—3	Dry Stator	Water-grease	1923
	*Also Germany				*approx. years

signs. Hence, further corrosion is negligible. Usually means are provided for circulating the water within the motor in order to insure uniform temperature throughout the motor and to aid the dissipation of heat.

The Fairbanks, Morse and Company wet-stator motor is illustrated in Fig 2. This motor is very similar to the English-made Hayward-Tyler motor and in fact it is manufactured under Hayward-Tyler patents. Until recently, Fairbanks, Morse imported the Hayward-Tyler motor for use with Fairbanks, Morse pumps.

The Pleuger Pumps, Inc. wet-stator motor is illustrated in Fig. 3. The latter motor is of German design but is now manufactured in Lancaster, Pa. as well as in Hamburg, Germany. Although the wet-stator motor has not been widely used in the United States, it has been sold by both English and European manufacturers all over the world. In service, it has proved very successful. Motors of this type up to 450 hp are built in England and up to 1000 hp in Germany.

Dry-Stator Types

In the early 1920's the dry-stator motor was developed in Europe by adopting the idea of the European refrigerator motor which was built with a very thin stainless steel tube in the bore of the motor which sealed the refrigerant off from the stator windings. In the case of the submersible motor, the rotor, bearings, etc. are submerged in a coolant of water, water-oil or water-grease emulsions. Where the coolant used is water, it may or may not be sealed in the motor, depending upon the individual design. One of the advantages of this motor from a manufacturing standpoint is that standard varnished windings can be used. In the case of some designs, the dry-stator motor has been found to be very sensitive to temperature rise. A very substantial rise in temperature has been known to cause collapse of the stainless steel tube. Some manufacturers of this type motor have overcome this potential weakness by filling the stainless steel tube or "can" with certain very stable polyester resins and fillers having a high thermal conductivity. Dry-stator motors of this type have proved highly successful. The Franklin Electric Company's dry-stator motor of this type is illustrated in Fig. 6.

Oil-Filled Open-Winding Type

The largest submersible motors manufactured in the United States are of the oil-filled open-winding type. From a manufacturing standpoint, this type is very desirable because the oil lubricates all wearing surfaces and protects all parts from corrosion, thus permitting the use of less expensive carbon steel and cast iron parts. Another advantage is the fact that standard varnished windings may be used. Some makes using standard windings are so constructed that they may be wound in any well-equipped motor repair shop. Most designs provide means for circulating the oil which helps to maintain fairly uniform temperatures throughout the motor and aids in the dissipation of heat. Cer-

tainly a most important part of an oil-filled motor is the seal between the shaft and the motor housing at the top of the unit. The seal must be of such design as to limit the loss of oil to a very small amount. Otherwise, the oil in the water being pumped would become objectionable. Also, means would have to be provided to replenish the oil supply. Two types of seal are used—a mercury seal and a mechanical seal. The mercury seal is recognized as being very satisfactory, but in the smaller size motors it is considerably more expensive than a mechanical seal. One of the minor disadvantages of an oil-filled over a water-filled motor is the greater drag imposed on the rotor by the oil due to the viscosity of the oil. However, some manufacturers of this type of motor guarantee as high efficiencies as competing manufacturers guarantee for their wet-stator motors. Figure 4, showing the motor design of Byron Jackson Pumps, Inc. and Figure 5, showing the General Electric Company motor design, illustrates two different designs of the oil-filled type submersible.

Plastic Impregnated Stator Windings

One of the more recent submersible motor designs (Fig. 7) is that of U. S. Electrical Motors, Inc. of Los Angeles, which consists of a stator with plastic lined slots. After winding, the slots are completely filled under a special process with a plastic which fuses with the plastic liner, thus sealing the windings completely. This motor is filled at the factory with the coolant and the unit sealed. Motors up to 3 hp are filled with a water-oil emulsion; larger units are filled with water and glycol. General Electric Company uses a somewhat similar design for motors in sizes of 0.33 to 5 hp. The coolant used is a mixture of water and glycol. General Electric motors in sizes larger than 5 hp are open-winding type filled with oil. The design used by U. S. Electrical Motors for sizes larger than 3 hp is similar to the conventional dry-stator type except that all voids inside the stainless steel tube, or "can," are filled with a plastic in order to improve the cooling characteristics of the motor. Both the U.S. and G.E. motors are equipped with mechanical type of seals and neoprene diaphragms to provide for the thermal expansion and contraction of the coolant.

A motor with plastic impregnated stator windings is manufactured by Jack and Heintz, Inc.

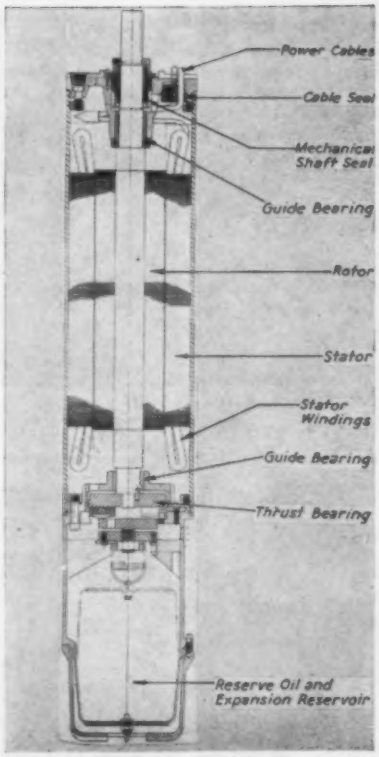


Fig. 5—SECTION of General Electric Co's. submersible motor. (Oil-filled motor with fechanical seal—5 to 125 hp.)

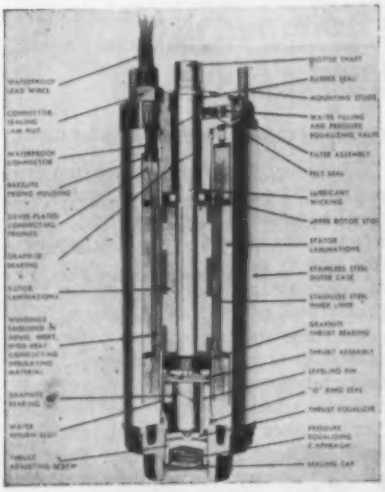


Fig. 6—SECTION of Franklin Electric Co's. submersible motor.
(Dry stator motor with rotor submerged in water and rubber and folt seal—1/3 to 20 hp.)

Discussion of Various Types

Where the liquid coolant is sealed in the motor, means are generally provided to take care of the thermal expansion and contraction of the coolant. This is usually accomplished by installing a diaphragm at the bottom of the motor housing which is free to move upward or downward as the volume of coolant within the motor changes with temperature change. Some manufacturers spring-load the diaphragm in order to insure a somewhat greater pressure on the inside of the motor than on the outside for the purpose of reducing the possibility of water in the well or sump from being sucked into the motor. In addition to the diaphragm, used to take care of the expansion of the water coolant, some wet-stator designs which provide for sealing in the water coolant, include a ceramic or metallic filter which permits water from the well or sump to enter the motor housing whenever the pressure on the outside of the motor is higher than on the inside of the motor. Another method of caring for the expansion and contraction of the coolant is that used by Byron Jackson Pumps, Inc. This method (illustrated in Fig. 4), is very simple and consists of a breather or balance tube on the outside of the motor extending from a level just above the top of the motor to a connection in the bottom of the motor case. Water from the well or sump is permitted to enter the tube at the top and flow freely through the tube to the bottom of the motor housing. Thus, any water that may enter the motor housing remains in the bottom of the housing due to the difference in specific gravity of the oil and water.

In any general comparison of Amer-

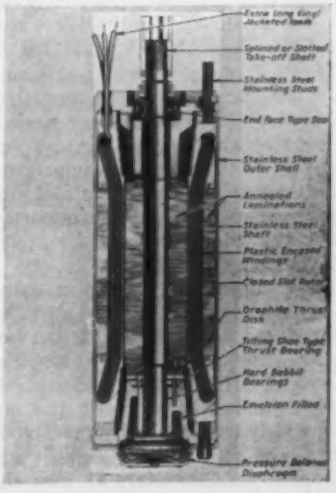


Fig. 7—SECTION of U. S. Electrical Motor Co's. submersible motor.
(Water—oil emulsion filled motor with mechanical seal—1/3 to 3 hp.)

The longest line of

PUBLIC WORKS EQUIPMENT

Three 16 by 14 inch single stage, double suction pumps, with A-C cage motors, in North Carolina plant.

Centrifugal Pumps — Vertical or horizontal, for sewage and activated sludge.

Blowers — For sewage aeration.

Rotary Vacuum Pumps — For use with vacuum filters in dewatering sludge.

Rotary Compressors — For compressing digester gas.

Dryers — For sludge dewatering.

Vibrating Screens — For removing solids from liquids; also in fertilizer manufacture.

Sifters — For grading fertilizer.

Roller Mills — For grinding fertilizer.

V-belt Drives — Constant and adjustable speed.

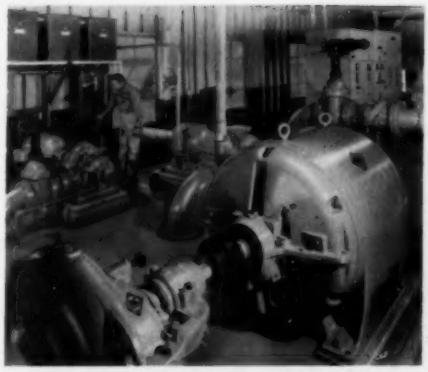
Motors and Control — For all drives over 1 hp.

Power Equipment — Steam turbines, condensers, pumps, water conditioning.

Electrical Equipment — Transformers, switchgear, circuit breakers, unit substations, generators, voltage regulators.

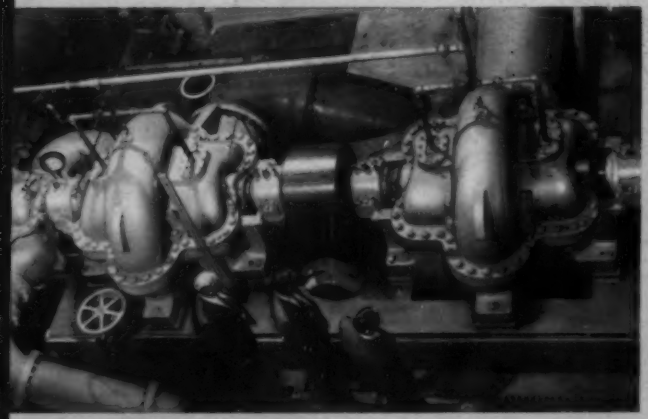
Engines—Diesel, gasoline and LP gas. Also generating sets.

Tractors—Graders, earth moving equipment.



This municipal installation is a good example of A-C's ability to furnish a complete pumping plant. Pumps, motors, control, switchgear, and transformers were all provided by this one company. Purchasing costs are reduced . . . responsibility unified.

The answer to all your needs



Milwaukee added 40 mgd to its pumping capacity by installing this 60-mgd Allis-Chalmers centrifugal unit in the space formerly occupied by one 20-mgd pumping engine. This new unit is driven by an Allis-Chalmers 3700-hp steam turbine which exhausts into an A-C condenser.

There's good reason why Allis-Chalmers is recognized as *the* leader in the public works industry. Nowhere else in the world will you find the convenience of a single source for so much public works equipment.

One look at this long list reveals that Allis-Chalmers can help you solve any problem, whether your operation is a sewage plant, water works, municipal power plant, street and highway construction, or other projects.

Imagine a line of pump sizes ranging in capacities of a few gallons per minute to huge 300,000-gpm units. And what a reputation they have. Not one centrifugal pump has ever failed to meet its guaranteed efficiency.

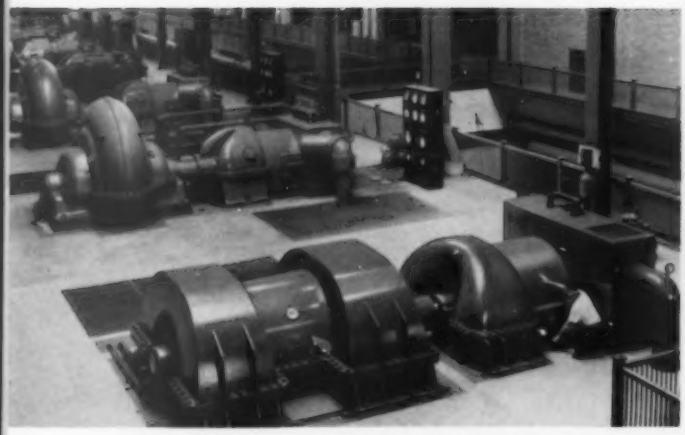
Pumps are only a part of the extensive line of equipment manufactured by Allis-Chalmers. There are motors of every type for operating every size pump, and control for every motor. There is also every type of power generating and power distributing equipment helping municipalities all over the world to grow and prosper.

Allis-Chalmers will help you analyze your problem and select the proper equipment for your needs.

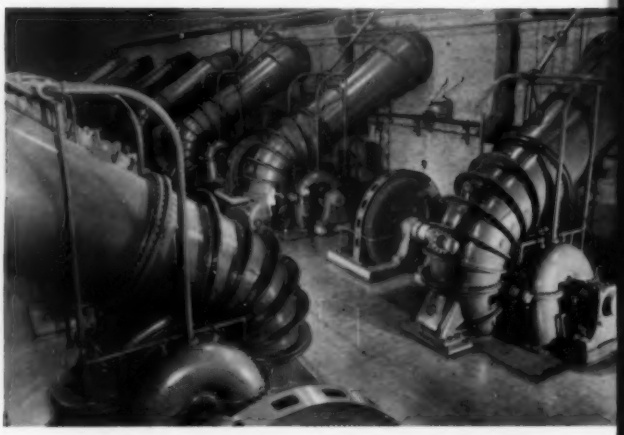
ALLIS-CHALMERS

25 C 6607E

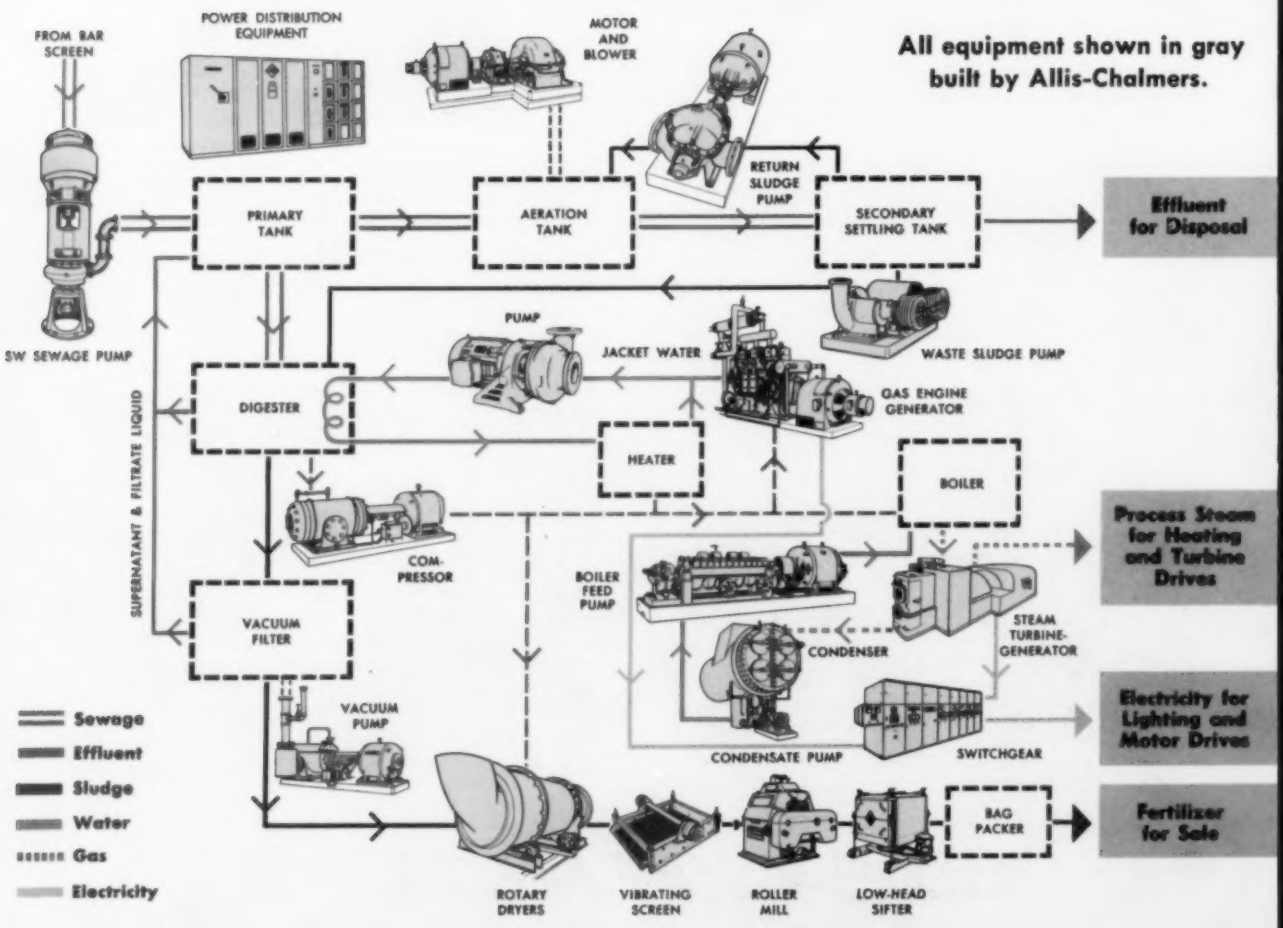
Allis-Chalmers



At the Metropolitan Sanitary District of Greater Chicago, West-Southwest sewage treatment plant, this 200,000 cfm, 8½ psig, four-stage axial is used as a base load machine. The centrifugals in the background provide the balance of the capacity needed, and meet load swings.



Twelve 72-inch centrifugal pumps at the Racine Ave. Station, Sanitary District of Chicago. They range in capacity from 375 to 500 cfs. They are driven by Allis-Chalmers synchronous motors, ranging in size from 1000 to 1750 hp.



helps you

PUT WASTE TO WORK

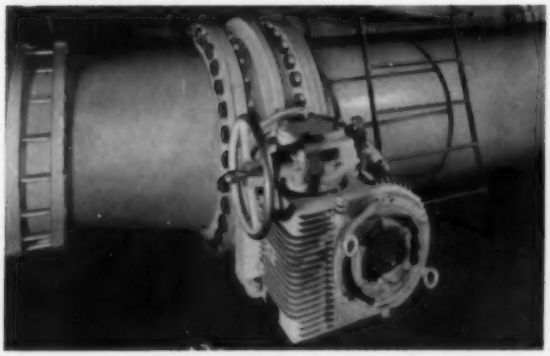
Allis-Chalmers 16 by 14 in. vertical sewage pump on combined storm and sanitary sewer main.

Plan sewage disposal system to help pay for itself

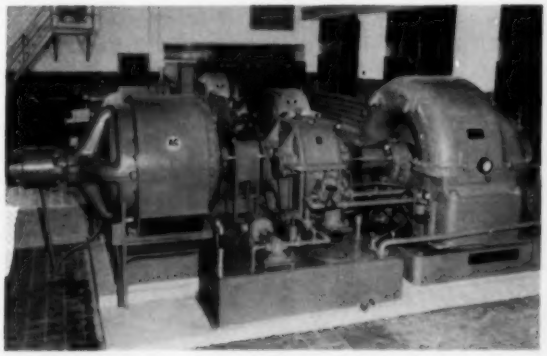
Expansion is the goal of every progressive community, and with expansion comes rising costs in added sewage plant facilities and equipment. Allis-Chalmers experience in public works systems can help you with a profitable expansion or modernization program.

The sludge flow sheet shows the variety of Allis-Chalmers (shaded) equipment used to extract valuable by-products, and how many communities are applying them to cut plant operating costs. Some are finding the sale of fertilizer defrays as much as two-thirds the cost of plant operation. Digester gas is being used to supply power and light needs.

Take advantage of Allis-Chalmers public works experience as other cities have done. Call your nearby A-C office, or write Allis-Chalmers, Milwaukee 1, Wisconsin.

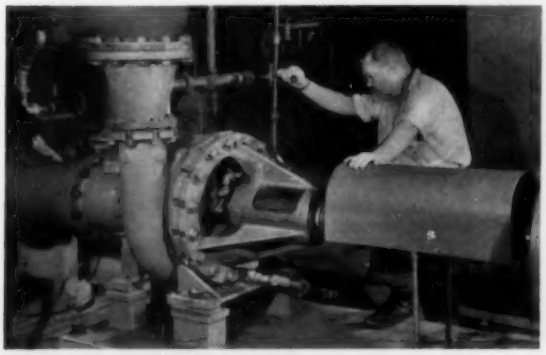


Close-up of Allis-Chalmers butterfly valve. A-C builds many designs of valves, including units conforming to American Water Works Standards.



Three multi-stage centrifugal blowers, rated at 8 lb gauge, in southern sewage plant. Capacities: 27,000 cfm, 10,000 cfm and 15,000 cfm. All are driven by Allis-Chalmers synchronous motors.

A-C 2500-kw, 3600-rpm WA-Series steam turbine-generator units with A-C switchgear in background.



Allis-Chalmers sewage pumps have wide impeller openings, rounded impeller inlets to pass solids freely.

ALLIS-CHALMERS

ELECTRIC POWER EQUIPMENT FOR PUBLIC WORKS

Rear view of 3000-kva, 4160-2400-volt unit substation with both incoming line section and distribution feeder section consisting of metal-clad switchgear.

Generation...
Distribution...
Control

Allis-Chalmers can supply a major percentage of all power generation, and electrical control and distribution equipment for public works. Included in the power generation line are steam turbine-generator units, surface condensers, condenser and boiler feed pumps, water conditioning service and equipment.

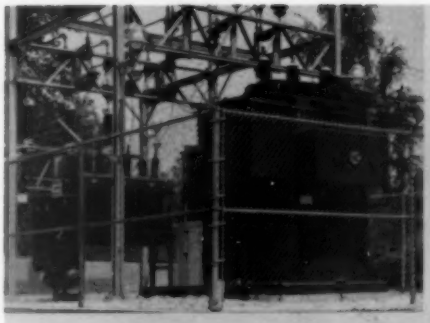
The range of electrical products includes all types and sizes of motors from 1 to 100,000 hp and up, and control to suit every application.

Allis-Chalmers indoor and outdoor high and low voltage switchgear provides maximum protection and flexible control of power distribution circuits. All units are metal enclosed, factory built, so they need only be bolted in place and lines connected. Switchboards are custom built to fill your needs.

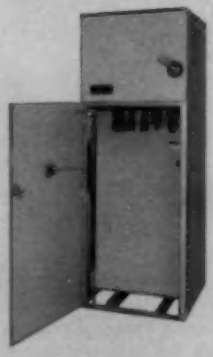
A-C builds a complete line of power and distribution transformers. Most sizes can be cooled with either oil or *Chlorextol* non-inflammable liquid, or they can be of the air-cooled type.

Load center, single circuit and multi-circuit unit substations are built in standard ratings to meet every application. They are completely factory built and can be installed adjacent to equipment being served.

Chlorextol is an Allis-Chalmers trademark.



Allis-Chalmers outdoor substation protects and controls the electrical power supply for a pumping station.



Motor Controls:
Dependable start-stop control for all sewage processing apparatus, in both single and grouped units. Simplified installation requires only connection to leads for operation. Expandable design permits easy addition of more cubicles.

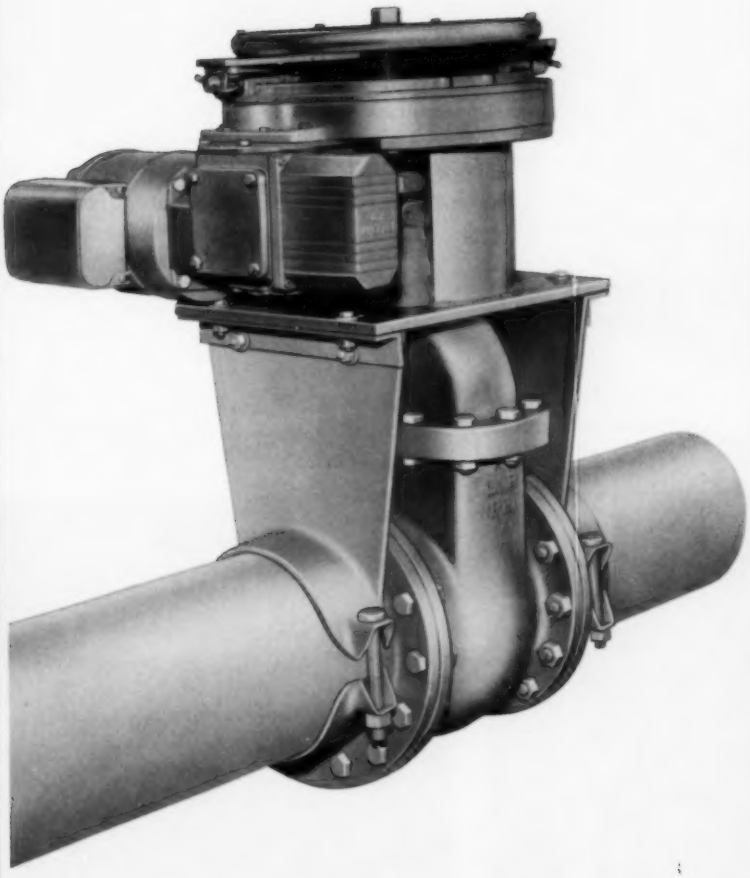
ALLIS-CHALMERS

1192 South 70th Street
Milwaukee 1, Wisconsin

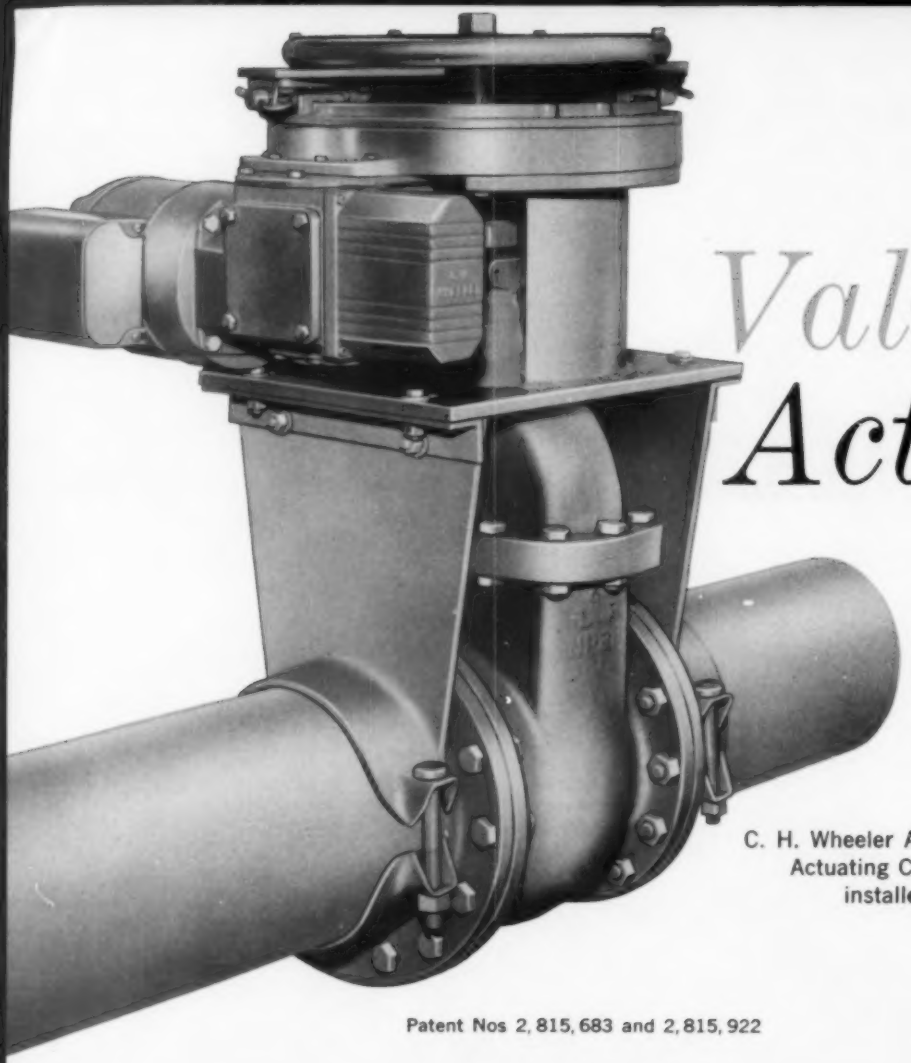
LITHO IN USA 56J-

CATALOG V-200

C. H. Wheeler Valvmatic Actuator



convert hand-operated valves to automatic operation



Valvmatic Actuator...

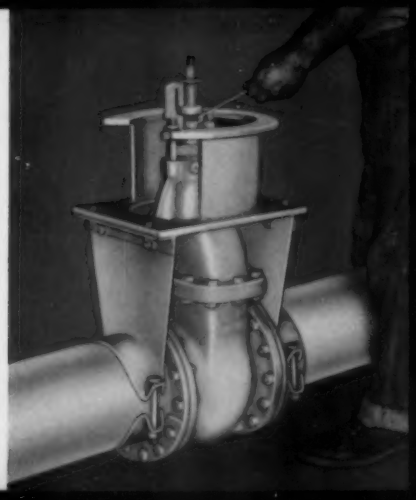
C. H. Wheeler Automatic Valve Actuating Conversion Unit, installed on pipe line.

Patent Nos 2,815,683 and 2,815,922

1 An 8" hand-operated gate valve installed in a pipe line, prior to conversion to a C. H. Wheeler Valvmatic Actuating Unit.

2 Mechanic first mounts the adapter brackets to the pipe line or valve flange as required. He then checks to see if both brackets are level and parallel.

3 The top adapter is placed i position and bolted to the adapte brackets by four bolts. Then th mechanic checks that top adapte is concentric with valve stem.



4

C. H. Wheeler Automatic Valve Actuating Conversion Unit. Install it yourself in only 4 hours . . .

- **without special engineering**
- **without disturbing your piping**
- **without replacing your existing valves**
- **operates electrically . . .**
- **installs in 6 easy steps!**
- **no special tools needed**

With C. H. Wheeler Valvmatic, you completely eliminate the need to hand-operate hard-to-turn or remotely-located valves. Instead, you simply push a button! You save considerably on first cost as well as installation costs, compared to other valve control mechanisms. And you operate with greater safety, especially in the case of inaccessible valves.

Valvmatic is ideal to open and close windows and operate other remote units, as well as to actuate valves. Get complete details on Valvmatic from either your representative or direct from C. H. Wheeler Manufacturing Company, 19th and Lehigh Avenue, Philadelphia 32, Pennsylvania.

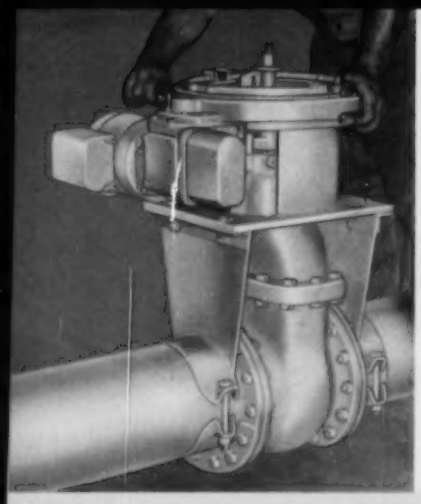
VALVMATIC ADVANTAGES

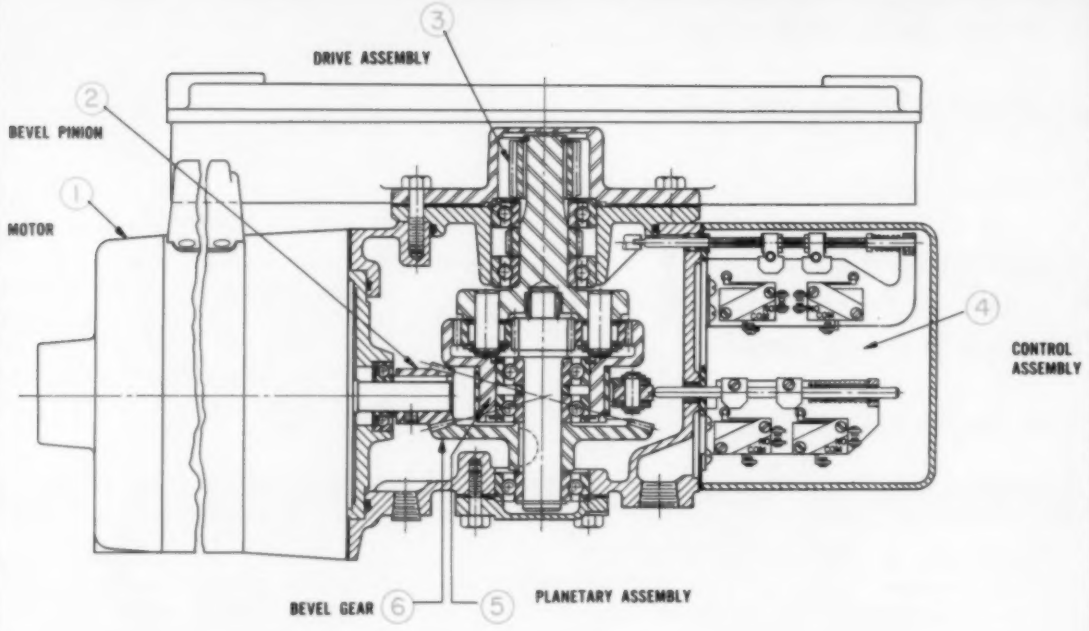
- Unusually fast, easy installation. Only simple tools needed. Valve remains in line; piping is left undisturbed. No machining of special valve nuts.
- Position and torque limits provided for both rotation directions to prevent valve injury. Position limits used for normal operation; torque limits in emergencies.
- Can be switched from one valve to another with ease.
- Low initial cost, minimum installation cost.
- Adaptable to nearly every application where valve handle does not rise, and where valve handle can rotate when valve is operating under power.
- Remote push-button operation; in the event of power failure, just pull two pins to operate valve manually.
- No special wiring needed. Plug into any 110 volt outlet.
- High-torque, instantly-reversible, totally-enclosed motor for dependable operation.

4 Next, the actuating mechanism is bolted to the top adapter.

5 Drive pin brackets are then bolted to the valve handwheel and the mechanic checks to make certain that they are centered and in line.

6 Final step is insertion of the se locking drive pins. After install tion of local or remote electric controls, unit is ready to operat





VALVMATIC Design Details

Above drawing shows construction and design details of Valvmatic Valve Actuating Conversion Unit. Note bevel drive, planetary gear assembly, control assembly and electric motor. Gear box, control box and drive assembly are sealed to protect against dirt and dust.

METALLURGY:

All gears are of chrome-molybdenum steel. Gear box and covers are cast iron. Ring gear housing is Meehanite.

MAXIMUM PRESSURE DIFFERENTIAL (Approx.)

for Valvmatic Actuating Conversion Unit

SIZE	12″	10″	8″	6″	5″	4″
PRESS. DIFF. (p. s. i.)	150	215	340	600	850	1350

NOTE: Above chart is for gate valves and figures are only approximate. It assumes 200 ft. lbs. output. Condition of valve affects the torque requirements. **Consult factory for other valve sizes and pressures.**

C. H. Wheeler Mfg. Co.

Serving Industry Since 1887

19TH AND LEHIGH AVENUE, PHILADELPHIA 32, PA.

PRINTED IN U.S.A.

TABLE 2

Actual Prices Paid for Submersible Pumps in Various Installations

Location	Owner	Year Purchased	No. of Units	Capac. gpm	Head ft.	Motor hp	Make of Motor	Cost per Unit	Cost per hp
Inglewood, Calif.	City of Inglewood	1953	2	750	75	20	B.J.†	$2,733.55	$137
Inglewood, Calif.	City of Inglewood	1953	2	750	90	30	B.J.	3,028.50	101
Inglewood, Calif.	City of Inglewood	1953	1	850	150	60	B.J.	3,666.00	61
Inglewood, Calif.	City of Inglewood	1953	1	3000	80	75	B.J.	4,295.68	57
Inglewood, Calif.	City of Inglewood	1953	2	1750	150	100	B.J.	4,585.00	46
Inglewood, Calif.	City of Inglewood	1953	2	1550	170	100	B.J.	4,585.00	46
Pasadena, Calif.	Foothill Mun. Water Dist.	1954	3	1550	350	175*	B.J.	5,897.00	34
Pasadena, Calif.	Foothill Mun. Water Dist.	1954	3	2450	305	250*	B.J.	7,297.00	29
LaCanada, Calif.	Foothill Mun. Water Dist.	1954	3	1400	485	200	B.J.	6,127.00	31
Henderson, Nev.	Basic Management, Inc.	1954	5	4200	300	400*	B.J.	10,600.00	27
Whitney, Nev.	Las Vegas Valley Water Dist.	1954	4	2400	462	350*	B.J.	10,350.00	30
Crescenta, Calif.	Crescenta Co. Water Dist.	1955	1	500	600	100	B.J.	5,875.00	59
Crescenta, Calif.	Crescenta Co. Water Dist.	1955	1	1000	600	200	B.J.	7,144.00	36
Beverly Hills, Calif.	City of Beverly Hills	1956	2	2400	112	100	B.J.	5,400.00	54
Beverly Hills, Calif.	City of Beverly Hills	1956	2	1500	265	125	B.J.	5,371.00	43
Monrovia, Calif.	City of Monrovia	1957	2	300	400	50	G.E.‡	3,220.00	64
Monrovia, Calif.	City of Monrovia	1957	2	600	210	50	G.E.‡	2,935.00	59
Monrovia, Calif.	City of Monrovia	1957	2	1500	234	125	G.E.‡	3,973.00	32

*2300-volt motors. All others 440-volt motors. All motors are 4 pole.

†Byron Jackson Pumps, Inc., Los Angeles, Calif.

‡General Electric submersible motors with Layne Bowler turbine pumps.

With the exception of the Beverly Hills installations, all pumps were purchased by the owner directly from the manufacturer.

ican-made submersible pumps with foreign makes, it may be stated that the efficiencies of the pump portions of the American-made units are higher than those of foreign-made pumps of comparable size. European manufacturers stack the bowls one upon the other and then hold them together with tie rods.

In Europe there has been a tendency to favor 2-pole designs, whereas in the United States, 4-pole designs have been more generally used. However, American manufacturers are beginning to look with favor upon the greater use of 2-pole designs. In the near future 2-pole motors in the larger sizes probably will be made available by American manufacturers.

Since most of the various types described herein have been successfully used in the smaller sizes in thousands of installations throughout the world, there can be no doubt as to the merits of submersible pumps as compared to conventional types. In fact since World War II, the submersible pump for 4-inch wells has been rapidly displacing conventional pumps in some areas. There are also many successful installations of large units in which the wet-stator and oil-filled types have been used.

Table 1 presents a tabulation of the principal submersible motor manufacturers in the United States, England and Europe and the types and sizes of motors offered.

Submersibles Used in Booster Pumping Stations

The use of submersible pumps as booster pumps has become quite common in Southern California. The installations listed in Table 2 have been designed under the supervision of the writer in the office of James N. Montgomery, Consulting Engineer. The submersible pumps listed in this table as having been installed at Henderson and Whitney, Nevada were chosen instead of conventional vertical pumping units because of the frequent high winds in that area which carry blow sand that can cause considerable damage to exposed mechanical equipment. In each case, comparative estimates showed the self-protected submersible installation considerably less expensive than either a vertical or horizontal conventional pump installation when the cost of the necessary protective building was added to the cost of the pump installation.

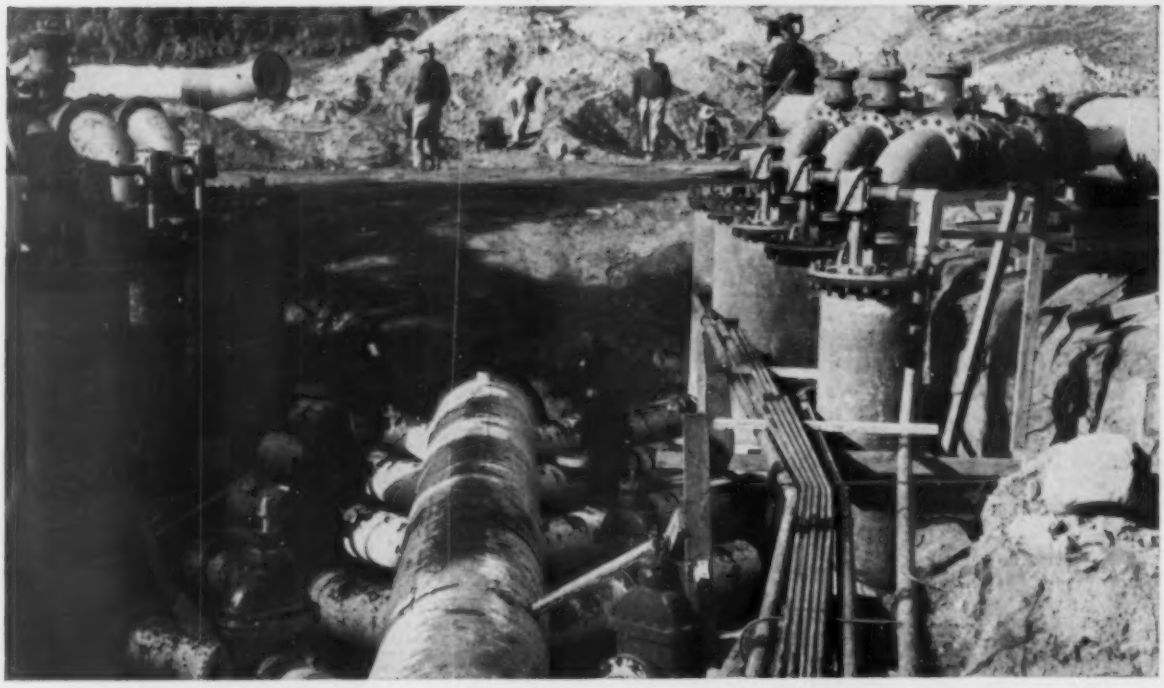
All submersible pumps listed in Table 2, except those installed at Henderson and Whitney, were chosen because in each case the pumping station was located in a residential area where noise was the important factor.

Table 2 indicates that small submersible units are relatively expensive but that the cost of 50-hp and larger units is not excessive. It is to be noted that prices of the smaller-size units have recently become extremely competitive. Therefore the prices listed in Table 2 for the smaller sizes are not indicative of current prices. Several manufacturers are now in a position to bid on units up to 150 hp which should have the effect of bringing prices of submersible pumps closer to those of conventional turbine pumps than has been the case in the past.

The last column in Table 2 gives the cost per horsepower. It should be kept in mind that since the cost includes both the pump and motor, the cost per horsepower is merely a rough means of comparison and is not a true comparison. This is due to the fact that for a given horsepower requirement a high-head low-capacity pump (pump alone) is more expensive than a low-head high-capacity pump because of the greater number of stages required in the bowl assembly.

As to Specifications

The specifications for the pump it-



CONSTRUCTION of Main Booster Pumping Station, Foothill Municipal District, Pasadena, California.
(Note simplicity of installation of submersible pumps and piping. See pictures of completed station on first page of this article.)

self may be essentially the same as for conventional close-coupled turbines.

Because of the wide differences in design of the various makes of submersible motors, a detailed specification which would provide reasonable safeguards and at the same time permit several of the leading manufacturers to bid is something of a problem. The following rather brief specification is being used in the office of James M. Montgomery, Consulting Engineer:

Pump Motors.

(1) The pump motors shall be of the vertical, submersible squirrel cage, 4-pole induction type and shall be of the sizes specified herein, designed for continuous duty under-water operation on 3-phase, 60-cycle, 440-volt alternating current. The motor shall be designed with sufficient starting torque and low starting current for across-the-line starting.

(2) The motor shall be enclosed in an oil-filled or a water-filled housing. Means shall be provided for circulating the oil or water.

Where the motor is enclosed in an oil-filled housing, the housing shall be sealed with a mercury seal, or a mechanical seal. The housing shall contain a reserve supply of oil sufficient for a ten-year period of normal operation and shall be provided with means for maintaining an oil pressure in the motor at least equal to that imposed by the water in the well.

Where the motor is enclosed in a water-filled housing, the motor bearings shall be completely water-lubricated and the amount of external-internal water interchange kept to a minimum by the action of a mechanical seal at the top of the motor. Any difference of pressure between the well water and motor water shall be equalized through the action of a neoprene diaphragm located at the bottom of the motor. The motor shall be designed in accordance with the latest standards of the A.S.A. and N.E.M.A. for the class of installation used.

Any baffling required to divert the water entering the barrel around and past the motor for cooling purposes shall be provided by the manufacturer. The manufacturer shall state whether or not such baffling is required for adequate cooling of the motor. Any baffling required shall be designed so that it will form a part of the pump and/or motor assembly and will not require attachment to the barrel.

Power Cable to Motor Element.

The power cable to the motor shall be impervious to moisture and shall be polyvinyl chloride insulated cable designed for under-water service. Where the motor leads emerge from the barrel through the suspension flange, they shall be permanently sealed through a water-tight packing or a pothead-type of seal. The cable shall be protected with a steel guard or an armored shield the full length of the cable from the entrance to the motor housing to the suspension flange. The cable size shall conform to the requirements of the California State Electrical Code. A cast or welded steel weatherproof terminal box shall be furnished and installed on top of the suspension flange and provided with plugged conduit outlets on either side of the box. The cable terminations at the terminal box shall be provided with terminal lugs.

In the proposal accompanying the above specification bidders are required to fill out the form—"Data and Information to be Furnished by Bidder" which appears on the next page.

The pump barrel may be specified to be furnished with the pump by the pump manufacturer or may be made a part of the construction contract and installed as part of the piping. The writer prefers the latter method.

The pump may be specified to be furnished with the discharge ell or with only a discharge neck which would terminate just above the suspension flange.

Installation

Because of the danger of damage to the protective lining in the pump barrel during installation or pulling of the pump, it is a good idea to use a lining which is not easily damaged. A ¾-inch thick cement-mortar lining has been found to be very satisfactory. The usual method is to excavate a wide trench to a level corresponding to the bottom of the suction connection. From this level, the excavation for the barrel is either bored with a cesspool rig or dug by hand. The bar-

BOOSTER Station, City of Inglewood, California.
(Each battery of five submersible pumps supplies a separate pressure zone. Small building houses switchgear.)

rel is then set in place and temporarily suspended from steel beam supports which in turn are supported on jacks or wedges to permit final adjustment. After final adjustment for line and grade, the barrel should be blocked to avoid shifting while the concrete encasement is being placed. Concrete placing must be done rather slowly to avoid floating the barrel. The barrel may be filled with water to help resist the tendency to float. In a multiple pump installation great care should be used in setting the barrels in order to insure perfect alignment.

A small air-release valve should be installed above the suspension flange which will relieve accumulations of air in the pump barrel. The air release valve should be equipped with a check valve, or a separate check valve should be installed to prevent air from being drawn into the barrel under certain conditions through the air release valve.

Where the pumping station is automatic, unattended and equipped with slow-opening pump control valves in the discharge piping, it is a good idea to provide means of automatically stopping the pump if the pump control valve fails to open after the pump builds up the normal discharge pressure. If such protective measures are not taken, the pump would continue to churn and eventually boil the water in the pump barrel if the pump control valve remained closed. Suitable protection can be accomplished either with a time delay relay or with a probe projecting into the pump barrel and connected to a thermostat set to open at a temperature lower than that which would damage the pump and motor.

Name of Pump Manufacturer.....
Name of Motor Manufacturer.....

PUMP DATA
- Pump No.....
- Bowl size.....
- Number of stages.....
- Diameter of shaft (in.).....
- Guaranteed Pump Laboratory Efficiencies
  - At design head (%).....
  - Maximum efficiency (%).....
  - Head at max. eff. (ft.).....
- Total net weight per unit (lbs.).....
- Total shipping weight per unit (lbs.).....

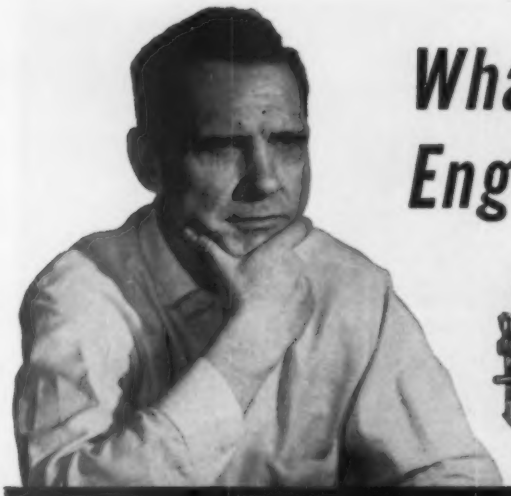
MOTOR DATA
- Motor Dimensions:
  - Length .....
  - Diameter .....
- Guaranteed efficiency at full load rating (%).....
- Efficiency:
  - ½ load (%).....
  - ¾ load (%).....
  - Full load (%).....
- Power Factor:
  - ½ load (%).....
  - ¾ load (%).....
  - Full load (%).....
- Starting torque (% of full load torque)
- Full load amperes.....
- Locked rotor amperes.....
- Total net weight per unit (lbs.).....
- Total shipping weight per unit (lbs.).....

ATTACH FOLLOWING DATA (3 copies of ea.)
- Guaranteed performance curves (showing shut-off condition)
- General catalog information describing pumps and motors to be furnished
- Method of baffling pump and motor if required to circulate water past motor, if required.

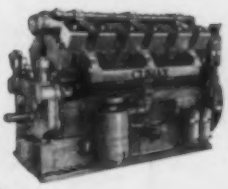
As shown in the illustrations, a submersible booster pumping station need not be housed unless located in a very cold climate. The electrical controls may be housed in a small building; or, if outdoor switchgear is provided, *all* housing can be eliminated.

Where a booster pumping station is required in a completely built-up area and where no sites are available, it is possible to install submersible pumps in an underground station below the street with outdoor switchgear located in a parkway or other practical location. The usual objection to underground pumping stations is based on the fact that they may be knocked out of service by a break in the piping or from general flooding of the area. This objection is eliminated with submersible pumps.

The writer wishes to express his appreciation for the cooperation of the various pump manufacturers in furnishing information on the various types of submersible pumps that has been assembled in this article.



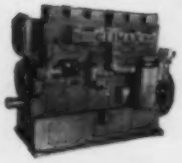
What Is An Economical Engine Investment?



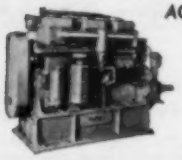
IS IT THE RIGHT ENGINE FOR THE JOB?

HOW EASY IS IT TO MAINTAIN?

A LITTLE THOUGHT ON THIS SUBJECT CAN SAVE A LOT OF MONEY!



WHAT ABOUT SERVICE?



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Your engine is an investment in work that needs to be done, now and over a long period of time. The efficiency of its work and the length of time depend substantially on effective maintenance and service. This adds up to simple arithmetic: the best engine for your purpose + the ease with which it can be maintained + fast and reliable service and parts facilities = *an economical engine investment.*

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Virginia: Richmond
West Virginia: Bridgeport, Charleston

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Florida: East Tampa, Jacksonville, Miami
Georgia: Atlanta
North Carolina: Charlotte, Fayetteville

MIDWEST
Illinois: Chicago, Grayville
Indiana: Indianapolis
Iowa: Waterloo
Kansas: Great Bend, Kansas City, Wichita
Kentucky: Lexington
Michigan: Detroit
Missouri: St. Louis
Nebraska: Omaha
Ohio: Cincinnati, Cleveland, Columbus
Wisconsin: Green Bay

SOUTH CENTRAL
Alabama: Birmingham
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Tennessee: Memphis, Nashville

SOUTHWEST
Arizona: Phoenix
Louisiana: New Iberia, Shreveport
New Mexico: Hobbs
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Relay Test for Motor Protection

Hampton Roads Sanitation District Commission saves vital equipment through preventive maintenance tests

by R. C. THAYER and J. E. SMITH

Mechanical Engineer and Electrical Superintendent, respectively, Hampton Roads Sanitation District Commission, Norfolk, Va.

IN THEORY, motors are safeguarded from overcurrent damage when there is a properly rated and accurately calibrated motor starter overoad relay in the power line. Recognizing that this is theory only, and with our own experience to disprove the "infallibility" of motor starter overload relays, the Hampton Roads Sanitation District Commission has been employing a new relay testing technique to assure that motors at sewage pumping stations are fully protected against destructive electrical fluctuations.

The Commission operates 38 automatic sewage pumping stations, as well as three fully attended sewage treatment plants. Since the greater number of the sewage pumping stations are each equipped with two electrically driven pumps operating on 220-volt, 60-cycle, 3-phase power, and total dependence for proper operation of the entire facility rests squarely on these units, it has been standard procedure to inspect this equipment daily. But despite these precautions, motors continued to fail.

So-called "expected outages," however, were not accepted as inevitable. By isolating and dismissing other possible causes of motor burnout, it seemed probably that overload protective equipment might not have been giving the degree of protection for which it was designed and installed.

As is customary, the Commissions' overload relay heaters were selected from tables of averages supplied by motor manufacturers. Predicated as these tables are on normal loads and average ambient conditions, a doubt existed as to their performance in locations where there are sharp deviations from the calculated ideal "norms." It was not unreasonable to speculate that this was the case here, and that motor losses were caused by improperly calibrated protective devices or those which were subjected to internal and external stresses that drastically changed their operating characteristics.

A new testing technique based on the Multi-Amp* Model 1010 portable high-current testing instrument was put into motion to fill this gap in the Commission's important preventive maintenance picture. The Multi-Amp Model 1010 is, fundamentally, a variable high-current power source which produces a primary current adjustable in stepless increments in a number of useful ranges from 0 to 500 amperes. Amperages are recorded on an ammeter while trip-times are registered on a timing device used in conjunction with the tester. The Multi-Amp connects to any standard 110-volt outlet and long flexible leads from its

* Manufactured by Multi-Amp Corporation, Newark, N. J.

PUMP ROOM of Lamberts Point sewage treatment plant contains main control center and three of four installed sewage pumps, ranging from 30 to 75 hp. A Multi-Amp test is being performed on mezzanine landing.

MULTI AMP being used for timing test on overload relay of a 75-hp magnetic motor starter. This is a critical test, as the relay is sensing reduced amperage through 60-to-1 transformers; that is, with 220-amp motor current the overload relay sensed only 3.7 amps. The relay must trip on slight current increase, because such small increases actually reflect 60 times those values for motor protection. In noisy locations it is nearly impossible to hear the relay trip. An ohmmeter (atop Multi-Amp) connected across the closed contacts of the overload relay detects tripping action.

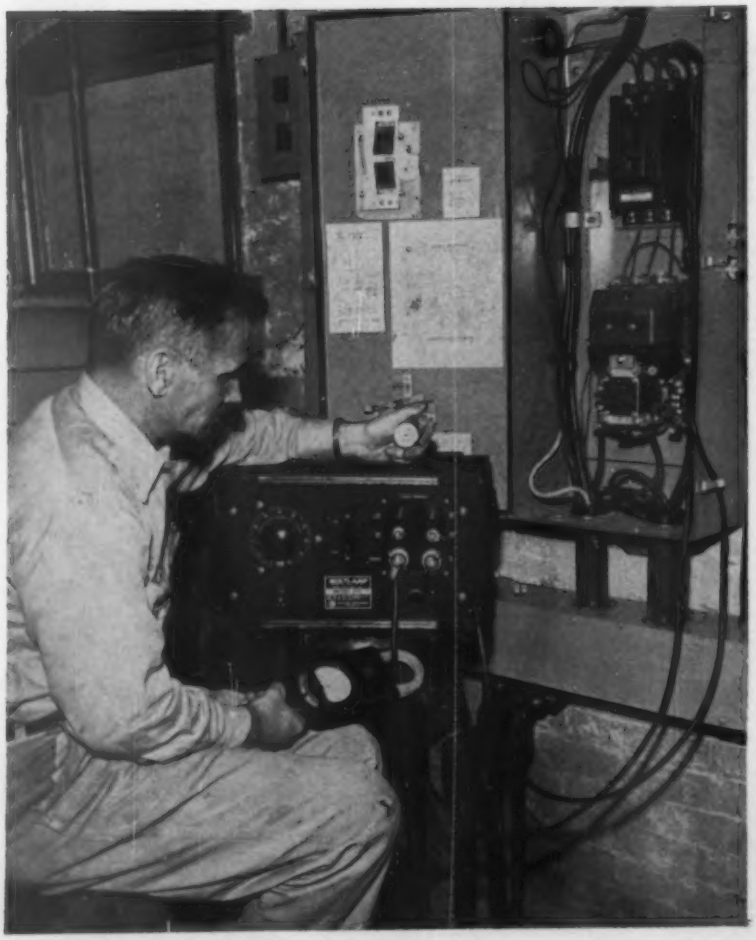
←

outlet terminals can be placed across the relay element without disturbing either the relay itself or adjacent equipment. Trip-time determination with any desired current is rapid, safe and convenient.

The Commission's preventive maintenance program is conducted as follows: In all two-pump installations, one pump is normally operated in lead position to handle the total load, while the second unit is on standby duty. A switch-over is made once weekly.

Since control equipment on the active unit is at operating warmth and overload relay on the standby motor is cold, proper compensation for testing purposes is made by applying a load equal to 100 per cent of the normal motor load on the operating (hot) relay for a 3-minute pre-heat period. This is followed by a 200 per cent load test to determine trip time. The result is recorded. After cooling for one hour, the relay is subjected to a 3-minute pre-heat at 100 per cent of the normal load, and a second trip-time test is performed at 200 per cent of the normal motor load. Again, the results are noted.

The inactive (cold) starter is immediately given a trip-time test at 200 per cent of rated capacity, allowed to cool for one hour, and then given a 3-minute pre-heat at 100 per cent of the normal motor load. final trip-time test is made at 200 per cent of the normal motor load. A and results are recorded. When the series of test runs is completed, the inspector can not only determine and recalibrate those overload relays which are inoperative or faulty, but his findings also are the basis for a choice between various types and different brands. The importance of



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TIMING TEST of one phase of the 100-amp circuit breaker of a 25-hp combination magnetic motor starter. Proper calibration of electrical protective devices is critical because of the great possibility of pump impellers becoming jammed, or their rotation otherwise becoming impeded, thus throwing dangerously heavy loads on the motors—loads which must be prevented from damaging the motors

maintaining a system of electrically-actuated protective devices which steadfastly remain in proper calibration cannot be overestimated, and the Multi-Amp method of detecting deficient relays has to date removed a number of suspected or potential troublespots.

We have already discovered that, for their purposes, certain types of overload relays stay in sufficiently good calibration for holding consistent trip-times under 1½ minutes. Other types which were formerly in use at the pumping stations showed serious misalignment, some failing to trip at 200 per cent normal loading after a 15- to 20-minute heat run. Although heaters for these unresponsive relays were selected from the usual normal tables, the actual protection which was afforded for vital motors was nil.

The Commission has already used the results of its own testing in writing specifications for new equipment. It now specifies overload relays of one make (found to remain consistently in proper calibration), regardless of the manufacturer.

An interesting by-product of the testing program developed when a prominent electrical manufacturer was informed that its larger relays were consistently out of calibration as evidenced by extensive Multi-Amp test results. The manufacturer, grateful for receiving accurate field data from a user, indicated that this information would be intimately applied to a program of redesign and improvement which was contemplated for its new overload relay line.

At present, the Multi-Amp technique has clearly defined the difficulties; the suspected problems have been successfully resolved by either calibrating or replacing improperly adjusted relays. Corrective action has meant renewed security in operating continuity and a significantly reduced motor maintenance and replacement bill.

TIME TEST on overload relay at electrical shop test bench prior to installation with a new 50-hp magnetic motor starter in an unattended sewage pumping station.

Gentile* FLOW TUBES

For Accuracy in Metering

*Gen-til'-ly

This 78" Gentile Type D Flow Tube of welded steel construction is only 78" face to face, and weighs only 8900 lbs.—many feet shorter and several thousand pounds lighter than a conventional venturi.

It is designed to handle 120 MGD of water at 60 PSIG and 68°F with a maximum head loss of 12" H_2O at these operating conditions, and with an accuracy within ±1% of the calibration curve furnished with it.

The Gentile Flow Tube is an impact-type head meter (differential producer) designed for accurate measurement and regulation of fluid flow. It consists, essentially, of a short spool piece, the inner periphery of which is equipped with two groups of pressure nozzles, one group pointing upstream and the other downstream. The nozzle groups are inter-connected by common pressure rings from which connections are made to the high and low pressure sides respectively, of a conventional indicating, recording or integrating meter. Flow Tubes differ from other variable head meters in that the taps are located at points of equal cross-sectional area. Therefore, the differential developed is a function of the velocity head and independent of the static head.

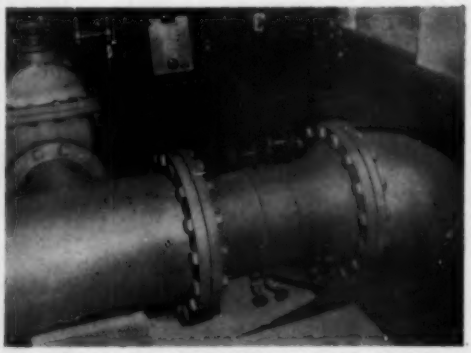
Flow Tubes are compact, comparatively light weight, relatively low in cost, and are easy to install since they require straight runs entering and following only when installed near throttling valves or regulators. And, Flow Tubes are available in types and D/d ratios to provide differentials that can be accurately measured with the least head loss.

Flow Tubes are furnished with head capacity curves based on laboratory tests. These data furnished with each Flow Tube makes our guarantee of exceptional metering accuracy possible.

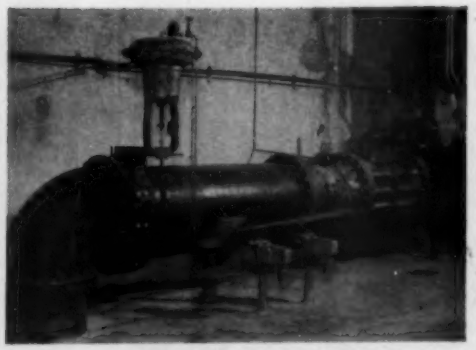
For further information, write us, and for specific recommendations, send us necessary flow data.

TYPICAL INSTALLATIONS

16" Gentile Flow Tube in Waterworks Pumping Station



12" Gentile Flow Tube in a Long Island Waterworks Pumping Station connected directly to 90° El.



One of twelve 20" Gentile Flow Tubes in Corpus Christi, Texas Filtration Plant

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For details circle 503 on inquiry card

Concentric Orifice Diameters

by ALEXANDER GOLDSTEIN

Senior Mechanical Engineer

West-Southwest Sewage Treatment Works, Sanitary District of Chicago

THIS IS A SECOND article on the determination of orifice diameters for fluid flow*. The phenomenal growth of the instrument industry with its innumerable fluid flow measurement applications provides ample testimony to the frequent necessity that size of the diameters of primary metering elements have to be made.

The vast amount of experimental work everywhere at its zenith requires orifice determinations so that flow measurements can be obtained for the gathering of vital information. There is little need to further emphasize the importance of improved methods for solving the orifice diameter problem.

* Ed. Note: The previous article appeared on p. 515 of the Nov. 1956 issue of *Water & Sewage Works.*

Graphic Solution

It is often advantageous to solve graphically a recurring mathematical problem. When such a method is accurate, rapid and convenient it is of considerable value. This article contains a nomograph, for the graphic solution of the orifice diameter problem. Its accuracy is well within one per cent of arithmetical computation and it, therefore, represents a serious attempt to solve the problem. It requires only that these basic factors be known: Rate of flow, differential pressure drop across the orifice, pipe diameter, and density (or specific volume) of the flowing medium. The factors must be in the units indicated on the graph.

The mathematical basis for the nomograph does not follow directly from the normal equation evaluating the diameter. The equation must be put in a suitable form. Since the transformation was found interesting and may be of some value it is presented here.

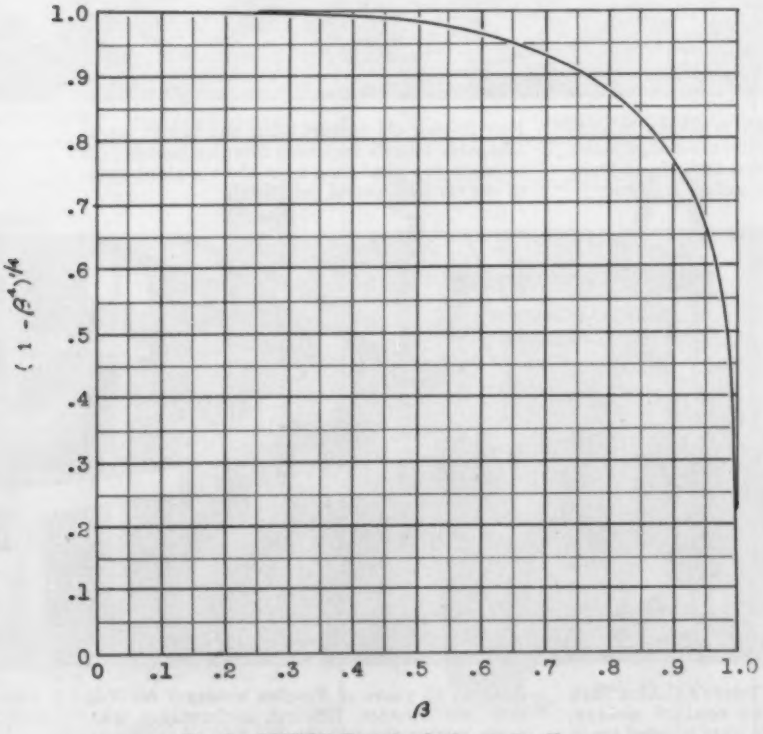

Fig. 1—ORIFICE diameter factor vs β ratio.

Symbols

The following symbols are use:

- A = the area of the orifice in square feet
- β = the ratio d/D, orifice diameter to pipe diameter
- C = the orifice coefficient not including the velocity of approach factor
- d = the orifice diameter in inches
- D = the internal pipe diameter in inches
- g = the acceleration of gravity, 32.16
- G = gallons per minute
- h = the orifice differential in inches of water column
- H = the orifice differential in feet of flowing fluid column
- M = pounds per minute
- q = cubic feet per second
- Q = cubic feet per minute
- ρ = density in pounds per cubic foot
- v = specific volume in cubic feet per pound

Basic Equation

The basic orifice equation for fluid flow is

$$q = CA\sqrt{\frac{2gH}{1-\beta^4}} \qquad (1)$$

In order to use a time interval of one minute and water column differentials, Equation (1) is converted into the following

$$Q = 1096.4\,CA\sqrt{\frac{2gH}{1-\beta^4}}$$

Introducing into Equation (2) the orifice diameter and giving **C** a val-

To get accurate flow measurement

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The integrated design of Simplex's complete line of measurement and control equipment gives your plants expansion flexibility . . . so today's units will fit with and work perfectly alongside tomorrow's . . . making for easy plant enlargement with negligible changeover.

We'll gladly work with your engineers to help you expand your old plant or plan a new one. Write today, outlining your problem. Simplex Valve & Meter Company, Dept. WS-58, 7 East Orange Street, Lancaster, Pa.

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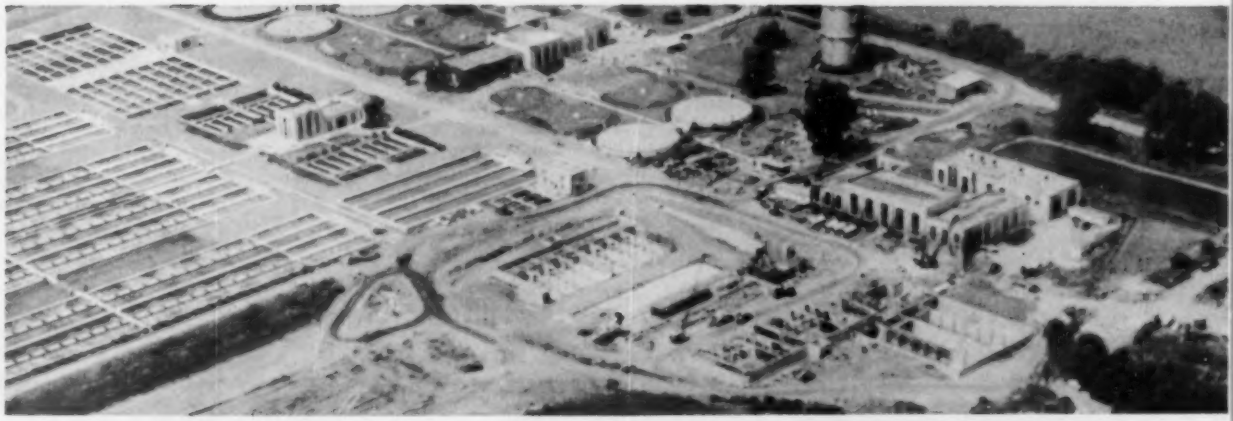

Columbus, Ohio faced tough problems in doubling the capacity of this activated-sludge plant. To get top plant performance, both old and new instrumentation had to be pulled together.

Now 20-year old venturi tubes and meters work alongside today's improved Simplex models . . . telemetering vital data from the big plant area to one central control point.

For new 40-mgd addition to Toledo's Collins Park Filtration Plant, Simplex venturi meters, gauges and filter controllers were selected again . . . making it 100% Simplex for the fourth time.

Reason: 35 years of Simplex accuracy for Toledo. No troubles. Efficient performance that saves money throughout the years—making it wisest to start with the best.

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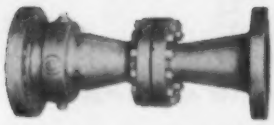

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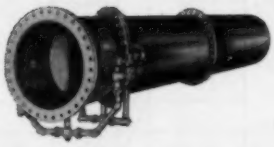
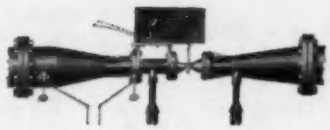
Dependable accuracy . . . minimum head loss. All sizes, all designs, in any metal.
SIMPLEX CATALOG 005



ELLIPTICAL VENTURI TUBES

Self-scouring flat invert for low velocity sewage, sludge, wastes.
SIMPLEX BROCHURE

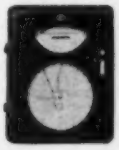


SLUDGE CONTROLLERS

Motor drive adjusts flexible rubber Venturi throat...keeps flow at control point!
SIMPLEX BROCHURE

PARABOLIC FUMES

±2% accuracy for open flows. 20:1 range.
SIMPLEX BULLETIN 801



TYPE H METERS

Mercury-float type. Gives you ±2% accuracy for up to 13:1 range.
SIMPLEX BULLETIN 402

TYPE MO METERS

20:1 range with ±2% accuracy.
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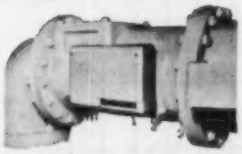

MODULAIR (R) FLOW CONTROLLERS

Automatically control filters, elutriation, plant discharges. Only one moving part . . . rubber throttling element in annular Venturi throat.
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TYPE S FLOW CONTROLLERS

Direct Venturi-actuated filter controllers. Operate when all power sources fail.
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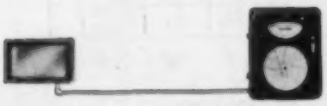
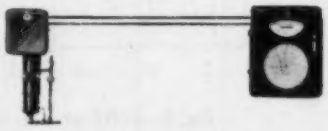
AUTOMATED FILTER TABLES

Program filter washing automatically. Inter-locked pneumatic system. Indicates, records, controls flow . . . shuts down, washes, rinses re-opens filters.
SIMPLEX BULLETIN 2200
FILTER GAUGES—SIMPLEX BULLETIN 1000



LAMINAIR (R) TRANSMITTER

Sensitive, fast, accurate pneumatic system centralizes in-plant control.
SIMPLEX BULLETIN 750



ORTHOFLOW (R) TRANSMITTER

Transmits data over in-plant circuits or telephone channels.
SIMPLEX BULLETIN 700

PITOT EQUIPMENT

Locates leaks and line breaks quickly. Light-weight, compact pitot rods, manometers, recorders.
SIMPLEX BULLETIN 1300

AIR RELEASE VALVES

Cut pumping costs by eliminating air binding at high points. Rugged 1" and 2" sizes.
SIMPLEX BULLETIN 1204

AIR INLET VALVES

Prevent collapse of thin-wall gravity lines when breaks cause sudden pressure drops.
SIMPLEX BULLETIN 1202

COMBINATION INLET-RELEASE VALVE

Compact. High air inlet and discharge capacity Boost pumping efficiency . . . prevent collapse.
SIMPLEX BULLETIN 1205

For details circle 505 on inquiry card

ue of 0.61, the following equations are obtained:

$$Q = 3.65\, d^2 \sqrt{\frac{h/\rho}{1-\beta^4}} \qquad (3a)$$

$$M = 3.65\, d^2 \sqrt{\frac{h/v}{1-\beta^4}} \qquad (3b)$$

$$G = 27.29\, d^2 \sqrt{\frac{h/\rho}{1-\beta^4}} \qquad (3c)$$

Limiting the discussion to equation (3a)

$$d = \sqrt{Q}\left(13.32 \frac{h}{\rho} + \frac{Q^2}{D^4} \right)^{-\frac{1}{4}} \qquad (4)$$

The value of d can now readily be computed by introducing the numerical values of all the symbolic quantities.

Transformation Of The Equation

In order to make a nomograph for a graphic and rapid determination of d, Equation (4) is not altogether suitable and must be put in a more appropriate form. This is done in the following manner:

Equation (4) is first rearranged to read

$$d = .5234\, Q^{\frac{1}{4}} \left(\frac{\rho}{h}\right)^{\frac{1}{4}} \left(1 + 0.0751 \frac{\rho Q^2}{hD^4}\right)^{-\frac{1}{4}} \qquad (5)$$

The factor $\left(1 + 0.0751 \frac{\rho Q^2}{hD^4} \right)^{-\frac{1}{4}}$ is expanded in accordance with the binomial theorem, resulting in the identity

$$\left(1 + .0751 \frac{\rho Q^2}{hD^4}\right)^{-\frac{1}{4}} = 1 - .0188 \frac{\rho Q^2}{hD^4} + .00088 \frac{\rho^2 Q^4}{h^2 D^8} \qquad (6)$$

If the third and following terms could be discarded under all conditions as being very small and not significant, the production of the nomograph would now be assured. But this is not possible since these terms are often appreciable.

Returning to Equation (3a) and solving again for d,

$$d = .5234\, Q^{\frac{1}{4}} \left(\frac{\rho}{h}\right)^{\frac{1}{4}} (1-\beta^4)^{\frac{1}{4}} \qquad (7)$$

The expression $(1 - \beta^4)^{\frac{1}{4}}$ has significance in that it shows the change in orifice diameter for flow in pipes compared to discharge from a plenum chamber.

Comparing Equations (5) and (7)

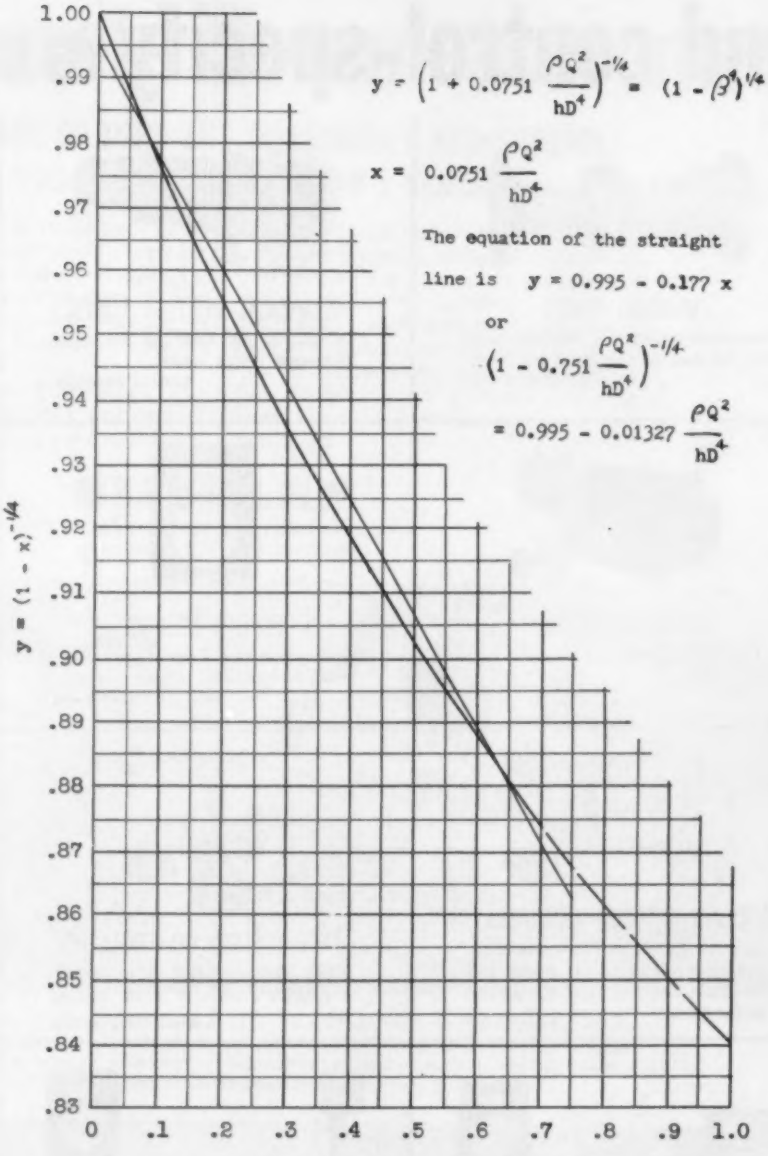


Fig. 2—PLOT of $y = (1 + x)^{-\frac{1}{4}}$ vs x and its straight line approximation.

$$(1 - \beta^4)^{\frac{1}{4}} = \left(1 + .0751 \frac{\rho Q^2}{hD^4}\right)^{-\frac{1}{4}} \qquad (8)$$

A curve, Fig. 1, is drawn having $(1-\beta^4)^{\frac{1}{4}}$ ordinates and β abscissas. Inspection of the curve shows that for values of β up to 0.80, $(1-\beta^4)^{\frac{1}{4}}$ and, therefore, its identity

$$\left(1 + .0751 \frac{\rho Q^2}{hD^4}\right)^{-\frac{1}{4}}$$

has values ranging from 1.00 to 0.87. Since the nomograph is for values of β not in excess of .80, values of

$$\left(1 + .0751 \frac{\rho Q^2}{hD^4}\right)^{-\frac{1}{4}}$$

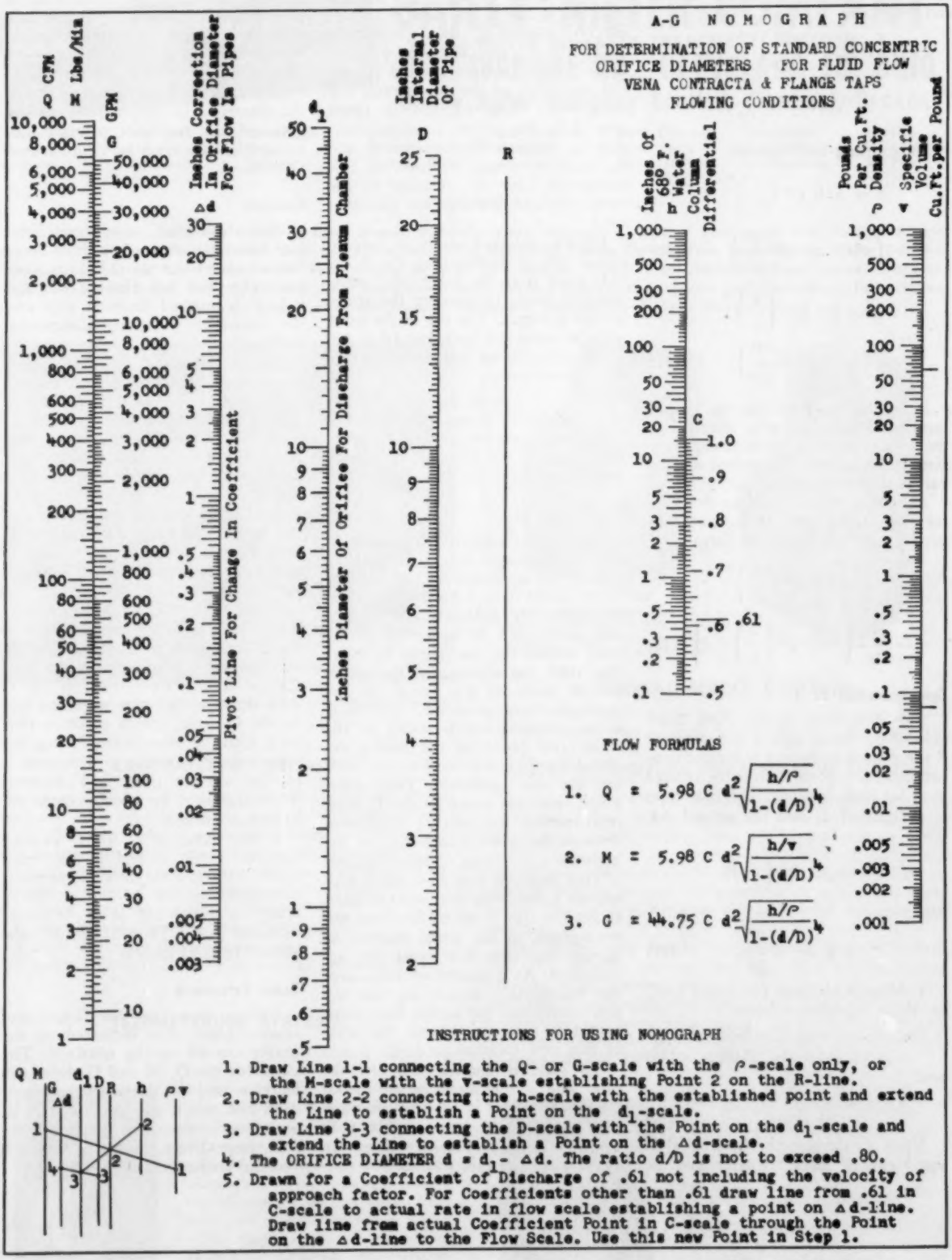
lower than 0.87 need not be considered.

Now let $y = \left(1 + .0751 \frac{\rho Q^2}{hD^4}\right)^{-\frac{1}{4}}$

and

$$x = .0751 \frac{\rho Q^2}{hD^4}.$$

A second curve, Fig. 2, is drawn having y or its equivalent $(1 + x)^{-\frac{1}{4}}$ ordinates and x abscissas. A straight line is drawn between the points $x_1\ y_1 = (0)\ (.995)$ and $x_2\ y_2 = (.65)\ (.88)$ approximating all values of the curve with a departure at all points of less than one percent. The equation of


A-G NOMOGRAPH
FOR DETERMINATION OF STANDARD CONCENTRIC ORIFICE DIAMETERS FOR FLUID FLOW VENA CONTRACTA & FLANGE TAPS FLOWING CONDITIONS
Q CFM
M Lbs/Min
G GPM
Inches Correction In Orifice Diameter For Flow In Pipe
Δd
Pivot Line For Change In Coefficient
Inches Diameter Of Orifice For Discharge From Plenum Chamber
d1
Inches Internal Diameter Of Pipe
D
R
Inches Of 680 F. h Water Column Differential
C
Pounds Per Cu.Ft. Density
ρ
Specific Volume Cu.Ft.per Pound
v
FLOW FORMULAS
1. Q = 5.98 C d² √(h/ρ / 1-(d/D)⁴)
2. M = 5.98 C d² √(h/v / 1-(d/D)⁴)
3. G = 44.75 C d² √(h/ρ / 1-(d/D)⁴)
INSTRUCTIONS FOR USING NOMOGRAPH
1. Draw Line 1-1 connecting the Q- or G-scale with the ρ-scale only, or the M-scale with the v-scale establishing Point 2 on the R-line.
2. Draw Line 2-2 connecting the h-scale with the established point and extend the Line to establish a Point on the d1-scale.
3. Draw Line 3-3 connecting the D-scale with the Point on the d1-scale and extend the Line to establish a Point on the Δd-scale.
4. The ORIFICE DIAMETER d = d1 - Δd. The ratio d/D is not to exceed .80.
5. Drawn for a Coefficient of Discharge of .61 not including the velocity of approach factor. For Coefficients other than .61 draw line from .61 in C-scale to actual rate in flow scale establishing a point on Δd-line. Draw line from actual Coefficient Point in C-scale through the Point on the Δd-line to the Flow Scale. Use this new Point in Step 1.

Copyright 1957 by A. Goldstein

Fig. 3—NOMOGRAPH for determination of standard concentric orifices.

the straight line is $y = .995 - .177x$ and therefore,

$$\left(1 + .0751 \frac{\rho Q^2}{hD^4}\right)^{-\frac{1}{4}} = .995 - .01327 \frac{\rho Q^2}{hD^4} \quad (9)$$

Substituting in Equation (5)

$$d = .5234\, Q^{\frac{1}{4}} \left(\frac{\rho}{h}\right)^{\frac{1}{4}} \left(.995 - .01327 \frac{\rho Q^2}{hD^4}\right) \quad (10)$$

$$d = .521\, Q^{\frac{1}{4}} \left(\frac{\rho}{h}\right)^{\frac{1}{4}} \left(1 - .01335 \frac{\rho Q^2}{hD^4}\right) \quad (11)$$

It will be observed that the second term of the last factor is identical to the second term in the expanded version of Equation (6), except for the value of the constant.

Equation (11) is used as the basis for the nomograph. It is first converted into the following form

$$d = .521\, Q^{\frac{1}{4}} \left(\frac{\rho}{h}\right)^{\frac{1}{4}} - \frac{.18}{D^4}\left[.521\, Q^{\frac{1}{4}} \left(\frac{\rho}{h}\right)^{\frac{1}{4}}\right]^5 \quad (12)$$

Determination of d

The first term on the right hand side of the equal sign is the value of **d** for discharge from a plenum chamber and the second term is the change in **d** for flow in pipes. The first term is designated $\mathbf{d_1}$ and the second **Δd.** Then

$$d_1 = .521\, Q^{\frac{1}{4}} \left(\frac{\rho}{h}\right)^{\frac{1}{4}} \quad (13)$$

and

$$\Delta d = .18 \frac{d_1^5}{D^4} \quad (14)$$

Putting Equations (13) and (14) in their logrithmic forms

$$\text{Log } (d_1) = \tfrac{1}{2} \log (Q) + \tfrac{1}{4} \log (\rho) - \tfrac{1}{4} \log (h) - \log (1.919) \quad (15)$$

and

$$\text{Log } (\Delta d) = 5 \log (d_1) - 4 \log (D) - \log (5.556) \quad (16)$$

Now a nomograph (and a slide rule) can be made to determine the value of **d**. If ½ log (Q) were a scale A, ¼ log (ρ) a scale B and ¼ log (h) a scale C, then graphically $d_1 = AB/C$, and scale A + scale B − scale C represents the graphical operation on the nomograph (or slide rule). Log (1.919) is taken care of by the proper fixed relationship in position between the **Q** and $\mathbf{d_1}$ scales. (A and C used in this paragraph have no relation to the same symbols elsewhere in this article.)

Having obtained $\mathbf{d_1}$ it is easy to obtain **Δd** by subtracting the 4 log (D) scale from the 5 log (d_1) scale, again properly positioning the scales for the constant. The use of the same scale to serve for both log (d_1) and 5 log (d_1) is an important feature of the nomograph. Then

$$d = d_1 - \Delta d \quad (17)$$

The value of **d** obtained from the nomograph can be checked by solving Equation (3a) for **Q**. It is good practice to do this.

Coefficient C

In the flow equations the coefficient of discharge not including the velocity of approach factor was assumed to be 0.61, a good value when the Reynolds criterion and expansion factor can be neglected. However, should the coefficient be other than 0.61, the appropriate correction can be made on the graph. A line is drawn from point 0.61 on the **C** scale (abutting the **h** scale) to the actual rate point on the flow scale. The **Δd** scale line is used as the pivot line for this operation. Then draw a line from the point on the **C** scale representing the correct coefficient through the point established on the **Δd** scale and extend to the flow line.

This obtained new flow value represents a flow rate that is to be used to get the size of an orifice from the nomograph in the usual manner as though the new flow were the actual flow. As a matter of fact, were the nomograph drawn up for the new coefficient the actual flow point would be represented on the scale at this new location.

To state it another way: if the flow rate is measured by an orifice whose coefficient is not 0.61, the flow rate through the same orifice with equal differential pressure drop can be obtained in this manner for conditions in which the coefficient is 0.61. Since the nomograph is a 0.61 coefficient graph the diameter must be obtained by using this new point flow rate. By making corrections in hypothetical flow for the coefficients the diameters in this manner can be obtained also for other primary metering elements such as Venturis and nozzles.

Example

Find the orifice, nozzle and Venturi tube diameters when 3475 cubic feet of air of density 0.1035 pounds per cubic foot are flowing through a 12-inch internal diameter pipe and the maximum metering differential is 20 inches of water column.

Draw a line on the nomograph connecting point 3475 on the **Q** scale with point 0.1035 on the **ρ** scale establishing a point on the **R** pivot line. Extend a line from point 20 on the **h** scale through the established point on the **R** line to its intersection with the $\mathbf{d_1}$ scale where 8.25 is read off. Extend a line from 12 in the **D** scale through 8.25 on the $\mathbf{d_1}$ scale to the **Δd** scale where 0.34 is read. The diameter d ($= d_1 - \Delta d$) is $8.25 - .34 = 7.91$.

If the value of **C** for a flow metering nozzle is 0.96, connect 0.61 in the **C** scale with 3475 in the **Q** scale establishing a point on the **Δd** line. Extend a line from 0.96 on the **C** scale through the point on the **Δd** line to the **Q** scale, which point is now used with the other scales having the same values as above to determine d in the already prescribed manner. The value of **d** for nozzle comes out to be 6.47 inches.

If the value of **C** for a Venturi tube is 0.985, extend a line from 0.985 in the **C** scale through the point established on the **Δd** line to the **Q** scale. Using this new point the throat diameter **d** of a 12-inch Venturi tube should be 6.40 inches.

Scale Extensions

Orifice diameters for larger and smaller pipes than indicated on the graph can be readily obtained. The values of the **Q**, **M** and **G** scales can be increased or decreased one-hundred-fold while the **Δd**, **D** and $\mathbf{d_1}$ scales are increased or decreased ten-fold, respectively. Scales **ρ**, **V** and **h** remain unchanged.

METERS : GAGES : CONTROLLERS
for Sewage Treatment and Water Supply

BAILEY METER COMPANY

WATER & WASTE TREATMENT DIVISION

1072 IVANHOE RD., CLEVELAND 10, OHIO

Bailey Meter Company Limited, Montreal, Canada

Atlanta	Charlotte	Cleveland	Detroit	Los Angeles	New Orleans	Pittsburgh	Seattle
Boston	Chicago	Dallas	Houston	Memphis	New York	San Francisco	St. Louis
Buffalo	Cincinnati	Denver	Kansas City	Milwaukee	Philadelphia	Schenectady	St. Paul

PRODUCTS

ARMORTUBE Cable, Basin and Reservoir Level Gages, Butterfly Valve Operators, Central Instrument and Control Panels, Chemical Feed Controllers, Elevated Tank Level Controls, Filter Operating Panels, Flow Meters, High Service Water Distribution Control, Loss of Head Gages, Main Meter Panels, Orifices, Flow Nozzles, Venturies, pH Recorders, Pump Speed Recorders, Rack Differential Gages, Rate Controllers, Sand Expansion Gages, Suction Well Level Recorders and Controllers, Telemetering Systems, Temperature and Pressure Recorders, and Weir and Flume Meters.

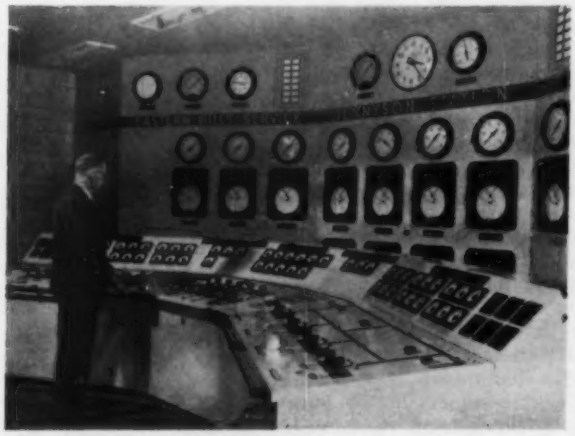


Figure 1—Centralized control room in a pumping station using desk and vertical-type panels.

CENTRALIZED CONTROL

The use of centralized control rooms in water supply and sewage-treatment plants helps designers to secure fully co-ordinated operation and greatly reduced man-power requirements. When planning centralized control installations you have available a line of Bailey products developed especially for this service. These products which are described in Bulletin G15-1 include:

1. Bailey Pneumatic and Electric Transmitters.
2. Bailey Receiver-Recorders and Indicators.
3. Bailey Pneumatic Control Components.
4. Bailey ARMORTUBE Cable for carrying Pneumatic Signals.

TELEMETERING SYSTEMS

Figure 2—Bailey Receiver-Recorder for pneumatic and/or electric signals.

Pneumatic and/or electric signals actuate Bailey Telemetering Systems. Either or both may be received in the Type WM55 Receiver-Recorder (Product Specification E12-5). Multiple receivers may be connected to one transmitter. Several flow measurements can be totalized on one record. Automatic control may also be part of the measuring and telemetering system.

For complete list of factors such as flow, level, pressure, temperature, pH, conductivity, turbidity and speed which can be measured and telemetered ask for Bulletin G15-1.

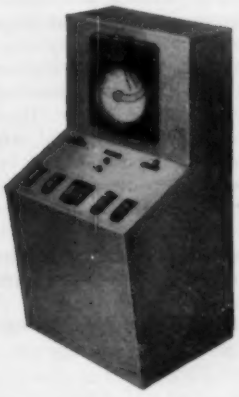


Figure 4—Bailey Filter Operating Consoles of the indicating type.
Figure 5—Bailey Filter Operating Consoles of the recording type.

CHEMICAL FEEDER CONTROL

Electric or pneumatic signals from Bailey Recorders may actuate chemical feeders, fluid sampling devices, alarms, or pump controls.

BAILEY METROTYPE INFORMATION SYSTEMS

Presents a means of gathering data and displaying it in digital or numerical form. This is essentially a system to sequentially select analog signals, measure them, and convert them to digital form. It may also log the numerical values on typed pages, indicate the measurements on numerical lamps, store the information on punched tape, or compare the measurements as they are made against preset high or low limits for detection of off-normal conditions.

Used for historical records, accounting and inventory control, test work, operating guidance, and plant or process monitoring. Measures widely scattered or locally grouped variables and provides local or remote display of gathered data at one or more points.

Equipment can be furnished as part of a complete measuring and controlling system or it can be used with existing primary measuring devices. Described in Bulletin E72-1.

Figure 3—Bailey Mechanically-operated Recorder.

BAILEY RECORDERS

Bailey Recorders measure flow of sewage, industrial waste, sludge, dirty water or other liquids in open channels or in pipelines. They also measure air flow, pH, liquid level in open and closed tanks and reservoirs and other factors.

Pneumatic and/or electric signals established by Bailey Recorders may actuate automatic control systems.

For details circle 506 on inquiry card

Magnetic Flow Meter

For measurement of liquid flow

by RUSSELL H. BABCOCK

Assistant Manager, Utilities Industrial Division of the Foxboro Co., Foxboro, Mass.

SINCE THE EARLIEST days of water works practice, there has been a continuing effort to improve existing methods of measurement and to develop new instruments for more accurate appraisal of system variables. One of the latest developments in this search for better measurement is the magnetic flow meter. Because flow is one of the principal variables on which the operation of installations depends, consideration of this new device is both timely and applicable.

The principle of operation of the magnetic flow meter is essentially the principle of electromagnetic induction first proposed by Physicist Michael Faraday in the early part of the nineteenth century.

History

In 1839, Faraday tried to measure the flow of the Thames River by applying his theory of electromagnetic induction. He placed two copper wires in the Thames River and, using the earth's magnetic field, attempted to measure the flow of river water. Because his voltmeter was somewhat less sensitive that he anticipated, the attempt did not succeed. Faraday reported in his notes as follows, "I constantly obtained deflections of the galvanometer but they were very irregular and were in succession referred to other causes than that sought for. The different condition of the water as to purity on the two sides of the river; the difference in temperature; slight differences in the plates, in the solder used, in the more or less perfect contact made by twisting or otherwise; all produced effects in turn; and though I experimented on the water passing through the middle arches only; used platinum plates instead of copper; and took every other precaution, I could not after three days obtain any satisfactory results."

No further work of major importance was done on electromagnetic metering of flow until Smith and Sleppian developed their magnetic ship's log, securing a patent on the device in 1917. At the present time, the United States Navy is engaged in building a ship's log based upon this principle.

Since that time, an impressive number of separate investigations have been carried out but in no instance was complete success achieved until the development of the Foxboro Magnetic Flow Meter. Earlier attempts failed to solve the problem of providing a high degree of accuracy, a wide range of meter sizes, and insensitivity to such effects as temperature and conductivity.

Ed. Note: This paper was presented before the New England Water Works Assn. and is here published by permission of the Association.

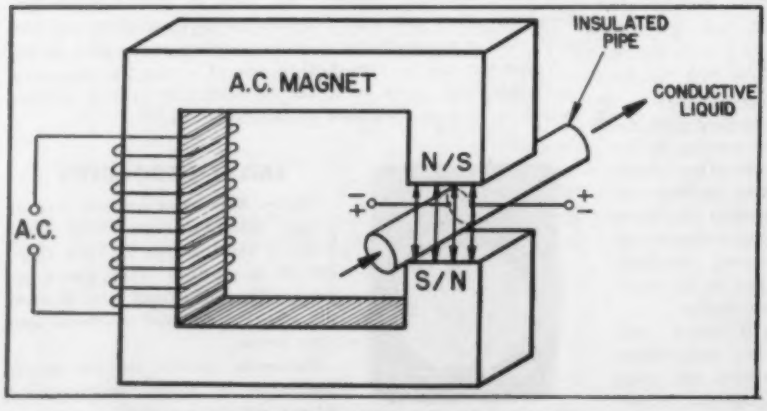


Fig. 1.—PRINCIPLE of the magnetic flow meter.

Principle of Magnetic Flow Meter

To understand how the magnetic flow meter meets the requirements of flow measurement, it is only necessary to review Faraday's law of electromagnetic induction. In general, this law states that if a magnetic field is generated in one direction and a conductor is moved at right angles to the field, a voltage will be generated which is directly proportional to the speed of the conductor and the strength of the field. In terms of instrument design, Fig. 1 shows that if an electromagnet generates a magnetic field of constant strength at right angles through a non-magnetic flow tube and a conductive liquid is passed through the tube, a voltage will be generated which is directly proportional to the rate of flow of the liquid. In direct contact with the liquid are two electrodes set into the tube diametrically opposite each other and insulated from the tube. To avoid shorting out the voltage, the tube is lined with an insulating material. The voltage signal from these electrodes is recorded in desired units of flow on an AC millivolt meter of special design. The equation of the magnetic flow meter is as follows:

$$E = K \frac{VHd}{A}$$

where:

- E = generated EMF, measured at the electrodes
- K = a constant for units of measurement
- V = volume of liquid per unit of time
- H = field strength between electrodes
- d = distance between electrodes
- A = cross sectional area inside pipe

The equation shows that the millivoltage output is equal to the product

of the constant for the unit of measurement, the volume per unit of time, the field strength, and the distance between electrodes, divided by the cross-sectional area of the pipe. This equation is entirely linear and includes no square root function to complicate recording.

Adaptability of the Meter

In evaluating the adaptability of the meter to typical water distribution and treatment applications, the question of turbulence or variation of the flow profile naturally arises. The magnetic flow meter reading is the average of the incremental velocities occurring within the pipe section between the two electrodes. Weigh tank tests have proved that here is no appreciable change in measurement accuracy between turbulent and laminar flow. The results of a test conducted by the Alden Hydraulic Laboratory on an 8-in. magnetic flow meter are shown in Fig. 2. (A crossection of the magnetic flow meter is shown in Fig. 3.) The deviations from the normal calibration curve occurred when a pipe elbow was installed directly upstream and when a swirl was artificially induced. In neither instance was any appreciable error observed.

Only when a conductor moves through a magnetic field will there be a measureable EMF generated across the electrodes. Therefore, in electromagnetic metering the fluid to be measured must be conductive. What constitutes a conductive fluid for purposes of electromagnetic flow measurement? The fluids encountered in water works applications normally have a conductivity greater than 100 micromhos. This is far above the minimum conductivity of 50 micromhos required for an 8-in. magnetic flow meter using 300 feet of lead wire between transmitter and receiver. It has been demonstrated that at values below 50 micromhos, the only undesirable effect is a wandering zero when there is no flow in the line. When flow resumes the meter reads accurately.

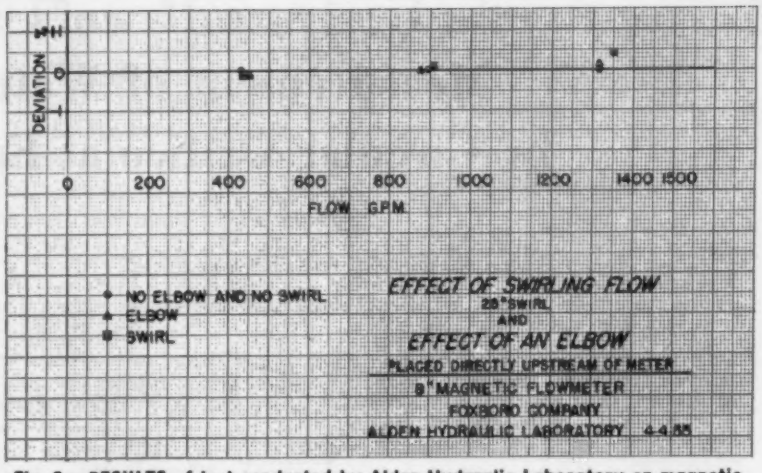


Fig. 2.—RESULTS of test conducted by Alden Hydraulic Laboratory on magnetic flow meter.

Since the magnetic flow meter is not subject to the effects of upstreams disturbances, it is possible to predict in advance of installation what the accuracy of the meter will be. The magnetic flow meter, including the transmitter and the recorder, has an over-all accuracy of 1 per cent. It is not necessary to add a safety factor to allow for possible errors from an improperly installed primary device, as done in calculating inferential meter accuracies. Regardless of the manner of installation, the accuracy of the magnetic meter remains unchanged at 1 per cent.

Application Advantages

To water works engineers, the magnetic flow meter has certain obvious application advantages. It adds no more loss of head to a hydraulic system than a straight pipe of the same length and size. Since it does not require a straight meter run, installation costs are apt to be much less than for other primary devices.

A 20-in. magnetic flow meter has been in service at the Chicago Southwest District Filtration Plant since the summer of 1956. John Baylis, Engr. of Water Purification, Chicago has published an article on this installation in "PURE WATER," a house organ of the Chicago Water Department. In it, he expresses satisfaction with the meter and reports that its high degree of sensitivity has enabled him to observe effects of line noise produced by the recovery cone of a Venturi tube down-stream (Fig. 4). In this instance, the meter is installed on the end of an elbow and directly upstream of a hydraulic rate of flow controller.

Other Applications

A number of meter installations have been made in the process industries; particularly, in the field of pulp and paper manufacture. The meter has obvious advantages for handling fluids containing high percentages of solids because there is no need for purge systems and there are no pockets or crevices in the flow tube where material can accumulate.

The sewage treatment field is also starting to use the magnetic flow meter. Many engineers consider it very nearly the ideal metering device for sludges.

The magnetic flow meter, based on principles of the earliest laws of electricity, is applicable to flow measuring problems that have plagued water works engineers for years. It gives promise to lead to more efficient plant operation and greater design flexibililty.

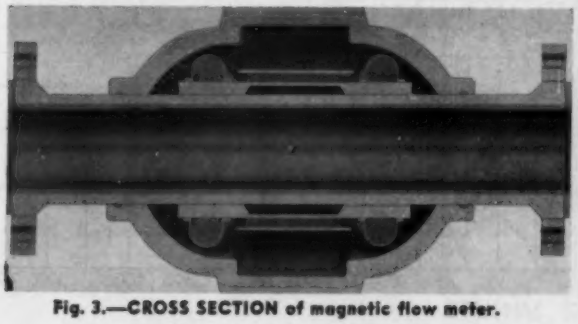


Fig. 3.—CROSS SECTION of magnetic flow meter.

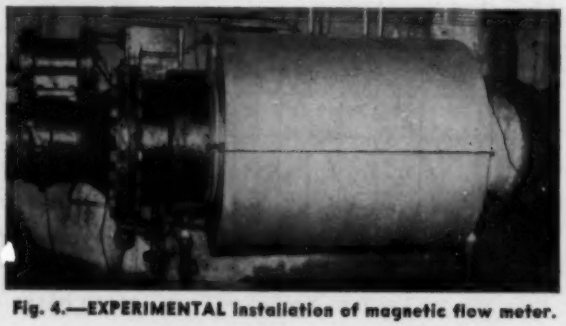


Fig. 4.—EXPERIMENTAL installation of magnetic flow meter.

Measurement of Water Flow by Circular Orifice at End of Pipe

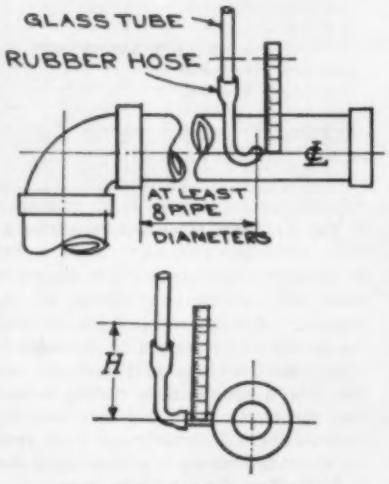
THE measurement of water flowing thru pipe lines by means of a circular orifice has been proven quite accurate, and experiments have demonstrated that a thin plate circular orifice installed at the end of a pipe line gives a rapid and accurate method for measuring such flows; the instruments being light and easily attached, permits of a simple method of testing pumping plants more accurately than the average weir that can be constructed in the field.

It is necessary that the pipe line be horizontal with no elbows, obstructions, or bends within 8 pipe diameters of discharge; the head should be measured from the center of the pipe at a point one foot or more back from the orifice.

The accompanying curve gives the discharge for 13 inch orifice on 15¼" inside diameter pipe, the formula being:

$G = KA\sqrt{2gh}$

Where G = Gallons per minute
A = Area of orifice in square inches
K = Constant depending on size of pipe and size of orifice.
H = Head in inches above center of discharge.

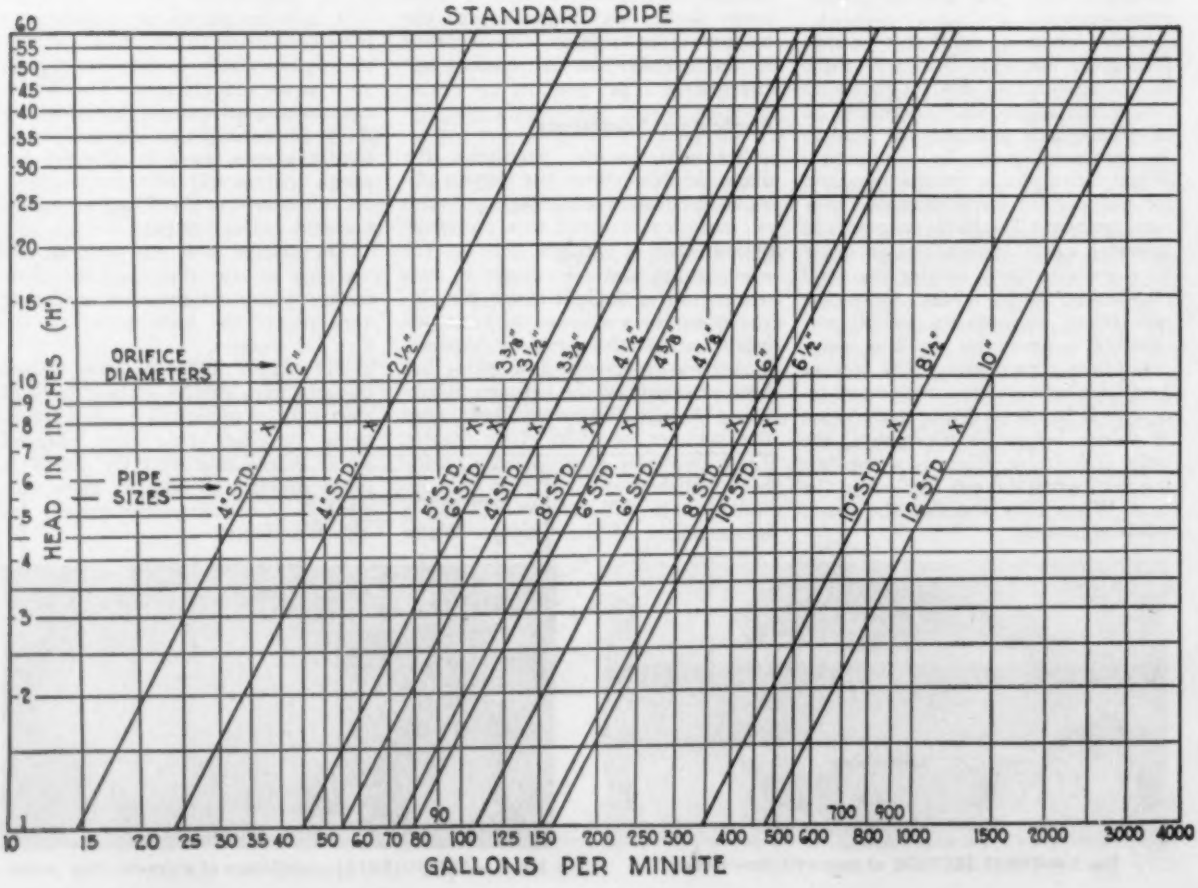


From *Peerless Pump Bulletin*

In calibrating these orifices a well constructed weir was used and the maximum variation of "K" was less than 3%. An average "K" was then taken from which these curves were constructed.

It is necessary that the orifice be running full of water and that "H" be at least one inch above top of the pipe for accurate results.

The head is measured by drilling and tapping for ⅛ in. pipe connection on the side of the discharge pipe one foot or more back of orifice, the hose connection installed and the height measured with an ordinary rule; the hole can then be plugged with an ⅛ in. pipe plug. It is very important that the ⅛ in. nipple does not extend inside the inner wall of the pipe and should be absolutely flush.



Sewage Flow Measuring Unit

Eliminates stilling chamber, debris accumulation, some maintenance and considerable cost

by EDWARD T. DAVIS

Partner, Chester Engineers, of Pittsburgh, Penna.

■ A new Parshall Flume type unit has been developed which not only measures sewage flow with much greater accuracy, but also requires little or no maintenance and markedly saves on construtcion costs as well. The unit is manufactured by Penn Instruments Div. of Burgess-Manning Co. and is designated Type ML.

The State School at Polk, Pa. (a client of the author's firm) beginning in December 1956, provided the scene for the initial use of the new unit.

Polk School Installation

The Polk School provided an appropriate testing ground for the new unit. The school is an institution housing approximately 3,400 mentally defective children, plus a medical and maintenance staff numbering 1,000. The school operates a central power plant for the manufacture of its own light, heat and power. It uses about 16,000 tons of coal yearly to heat approximately 10,000,000 cubic feet of building space. With the preparation of meals for the school's large population, the operation of a laundry servicing both patients and staff, and the round-the-clock use of toilet appurtenances by the patients, sewage facilities are in almost constant use.

The ML unit was particularly welcomed by the school maintenance staff because of the new disposal plant recently constructed so that the school can handle its own sewage problems. Lloyd McKissick, school maintenance engineer, reported that the new unit "worked perfectly" in all performances and was in keeping with the school's modern plant design. The writer was particularly gratified because the new unit ended a long period of trial and error in searching for adequate methods of sewage flow measurement.

Prior Methods

Years ago, Venturi meters were employed; but frequent stoppages occurred because of solids in the sewage. It was necessary to place the transmitting and recording mechanisms in a gravity flow line.

Later, an endeavor was made to measure flow into the sewage disposal plant by gravity through the use of weirs and orifices. But again the same type of defects resulted. Solids collected back of the weirs and orifice plates or the range of flow was limited or complicated.

In every case, measuring devices such as floats set to the side in wells for accurate readings required continuous maintenance because they were always plugging up and consequently not recording accurately.

Still later, Venturi flumes were used, but with the necessity of separate wells for recording the height of water, trouble was always experienced.

One of the first methods used to measure the depth of flow in Venturi flumes was by means of a low-range pressure recording gage reading from 0 to 1 foot or 0 to 2 foot. The pressure bulbs still had to be placed in wells to protect them; therefore, the same maintenance problems arose.

Venturi flumes were then discarded in favor of Parshall flumes, the capacity of which could be more readily calculated and which were more accurate than the Venturi flumes.

For years a search was made for a method of recording the depth of flow in the upstream part of the flume, where it would be unnecessary to use separate float wells. The development of the improved flow measuring unit answered this need. Its accurate measurement capabilities and its small maintenance requirement have solved the thorny problem of measuring liquids which contain solids.

Of the three main benefits of the new measurement unit—increased accuracy, construction economies, low maintenance requirement—the last is perhaps the most welcome because of the frequent, bothersome, and dirty task of sludge-cleaning which the old float or stilling well required. The unique construction of the new unit accounts for the small amount of maintenance necessary.

NEW Burgess-Manning Type ML Parshall flume unit, showing 4-inch steel float riding on water surface.

This allows rubbish, debris, etc., to ride through flume without becoming engaged with the float. Use of this unit eliminates necessity of stilling chamber, piping, fittings, concrete drywell, or water backfeed connections.

How the Unit Works

The salient features of the unit

are a 4-inch steel float, a float rod, and a core-and-coil transmitting device mounted in a waterproof metal case attached to the side of the flume or suspended from or attached to a cross piece at the entrance of the flume. The float rides on the surface of the water, being immersed only ½ inch. Consequently, seven-eighths of the float is completely out of the water and any rubbish, debris, etc., can ride through the flume without becoming engaged with the float itself. There is no need to clean out a float well, there are no pipes to become clogged, and the recording instrument itself is completely weatherproof. In addition, all exposed parts are made of stainless steel or (as in the case of the structure containing the core and coil) of cast iron properly painted to be impervious to weather conditions.

Because the need for the construction of float pipes, stilling wells, connecting lines, valves, backflushing device, etc., is eliminated, it is estimated that the installation of the new type unit results in savings of approximately 35 percent. This might mean several hundred or several thousand dollars, depending on the particular case. The installation itself is relatively simple and quickly accomplished. After completion of construction of the ML flume, which requires a shallower concrete pit dug below the surface than do the old types, only a day's time is needed for the installation of the recording meter.

Continuous Transmission

The meter can be installed anywhere up to 3,500 feet from the flume. Transmission is continuous, of the null balance inductance bridge type, necessitating just three twisted insulated and shielded wires to the receiver. Power is necessary at the receiver end only.

Each receiving instrument indicates flow on a uniformly graduated flow scale separate from the pen arm and having a length of at least 10 inches. The flow is recorded on a 12-inch diameter uniformly graduated chart designed for daily or weekly removal. The totalizer is of the cyclometer type, having at least seven digits and requiring only the use of zeros for multiplying factors. The receiver is housed in a pressed dust and moisture-proof case.

The receiver includes a two-phase servo motor for positioning the pointer, pen arm and totalizer with high and equal power over the entire scale range. Positioning of the servo motor is accomplished by the use of an electronic amplifier utilizing standard electron tubes with full-scale pen travel within 9 seconds. The entire receiver mechanism is mounted on a pivoted frame to permit inspection of all parts without the need for interrupting operation.

The Type ML meter is equally adaptable for measurement of flows across weirs or through open flow nozzles and is designed to be applicable to virtually every kind of sewage problem.

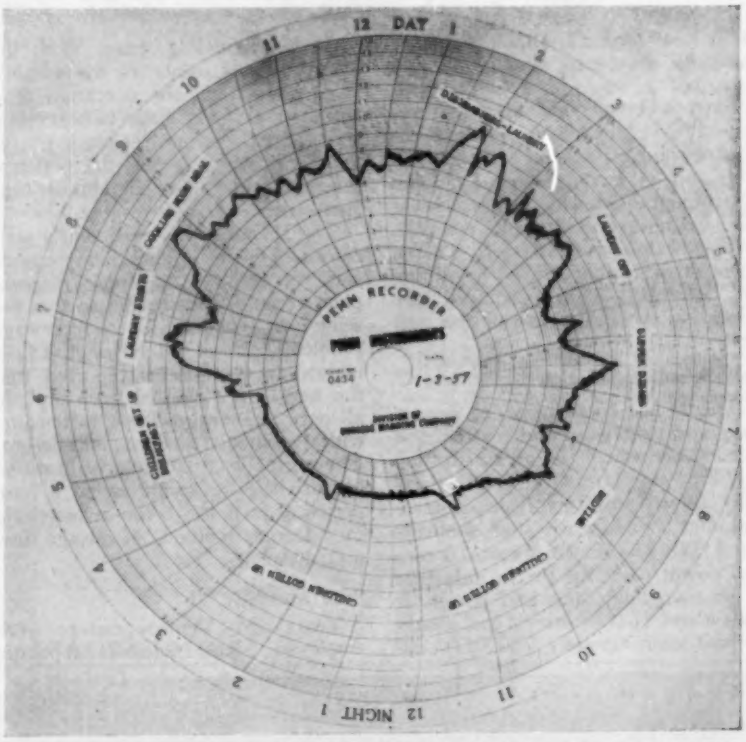
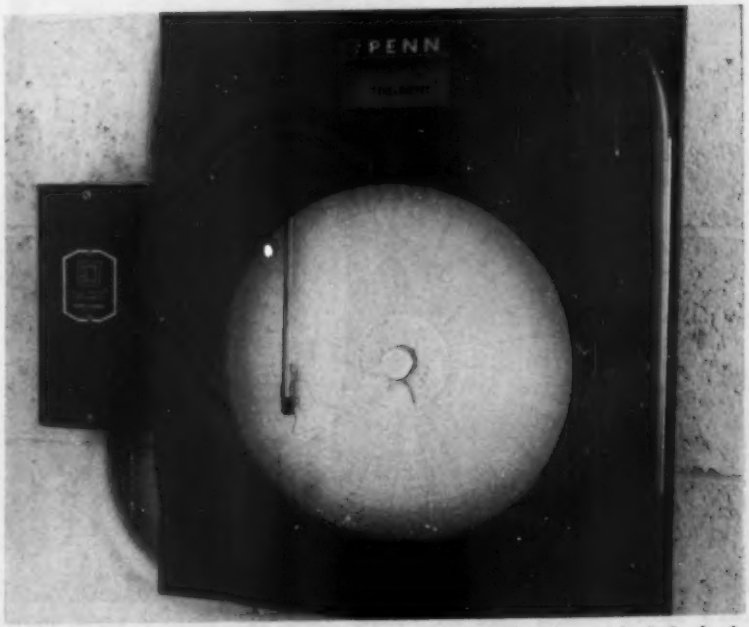


CHART of sewage flow for one day at Polk, Pa. State School, where first installation of new Type ML Parshall flume unit was made.



SEWAGE flow is recorded in 12-inch diameter, uniformly graduated chart designed for daily or weekly removal.

Totalizer (at top) is of cyclometer type. Receiver housed in pressed, dust and moisture-proof case can be installed anywhere up to 3,500 feet from flume.

Automatic Control of Pumping Stations

by J. S. WILLIAMS

Vice President Automatic Control Co., St. Paul, Minn.

■ AUTOMATION in its broadest sense is the substitution of mechanical-electrical devices for human decision and effort. Don't overlook that last word "effort." This means substituting another form of energy for a strong back.

Ultimately the supervisor will observe conditions in all key points via closed circuit television. Less critical operations will be monitored by alarm or annunciator devices working on the basis of "no news is good news." Thus the future supervisor will devote himself to the more important function of planning and record study. Before this can come about water works staffs will have to include competent electronic engineers and technicians for maintenance. Let there be no misunderstanding, we are highly optimistic about the wonders which the future holds. We merely caution against premature acceptance of something which today may not be economical nor practical. In the interim we must continue to advance in the direction of this future goal, we must take every step which is practical and economical, we must dream for without dreams there can be no progress, but we must also measure every plan against the yardstick of our capability. We can kill the dream, we can delay the future through involvement in a plan for which we are ill prepared.

Present Day Automation

To stand the test of time, to be practical, economical and workable, automation purchased for the present and the immediate future must be simple, rugged and most important understood and maintained by existing personnel. It has to be kept on duty 24 hours a day, 365 days a year with normal maintenance. The automatic system should be considered in two sections; namely, normal operation and emergency operation. Under normal operation, the attendant should have little to concern him other than an inspection or supervisory function.

There is no mechanical nor electrical device not subject to wear or ultimate breakdown. But the operator unharassed by unimportant duties can regularly inspect and thereby prevent trouble. Here is where the human ability of judgment and discretion can be fruitfully employed. Under normal operation the automation unit substitutes for the human operator in the determination of when and where the change is necessary. It dispatches electro-mechanical commands to start, stop or adjust a unit, correct for errors and maintain operation in the proper balance.

Automation can accomplish these things at a much higher speed and more surely than the human being. The automat cannot be distracted, nor bored, it needs no diversion nor entertainment, and it is not plagued with fatigue. Any good automation system has safeguards which signal when human judgment and decision are essential. A good system is simple and safeguards against normal failure and normal emergencies. The significant importance of any warning system is its ability to anticipate a condition. All protective devices must alert the operator before the condition or failure occurs. He may then take proper action to prevent the occurrence. This type of planning permits one to handle the faucets rather than wield the mop.

How to Buy Automation

A conservative approach avoids unnecessary equipment. A system should be equipped to provide efficient, trouble-free operation with reasonable safeguard and no more. The investment in gadgetry is unnecessary when dollars invested carefully in selected equipment will give every benefit needed.

The benefits of automation must not only pay for themselves, they must make money for the water utility. Systems which have outstripped their design, result in many operating obstacles. These conditions often require a measurement at one point with transmission of intelligence to another. Here even more than on the simple job the equipment being purchased should be closely scrutinized. Not every product is of equal quality, and any equipment considered should pass these questions:

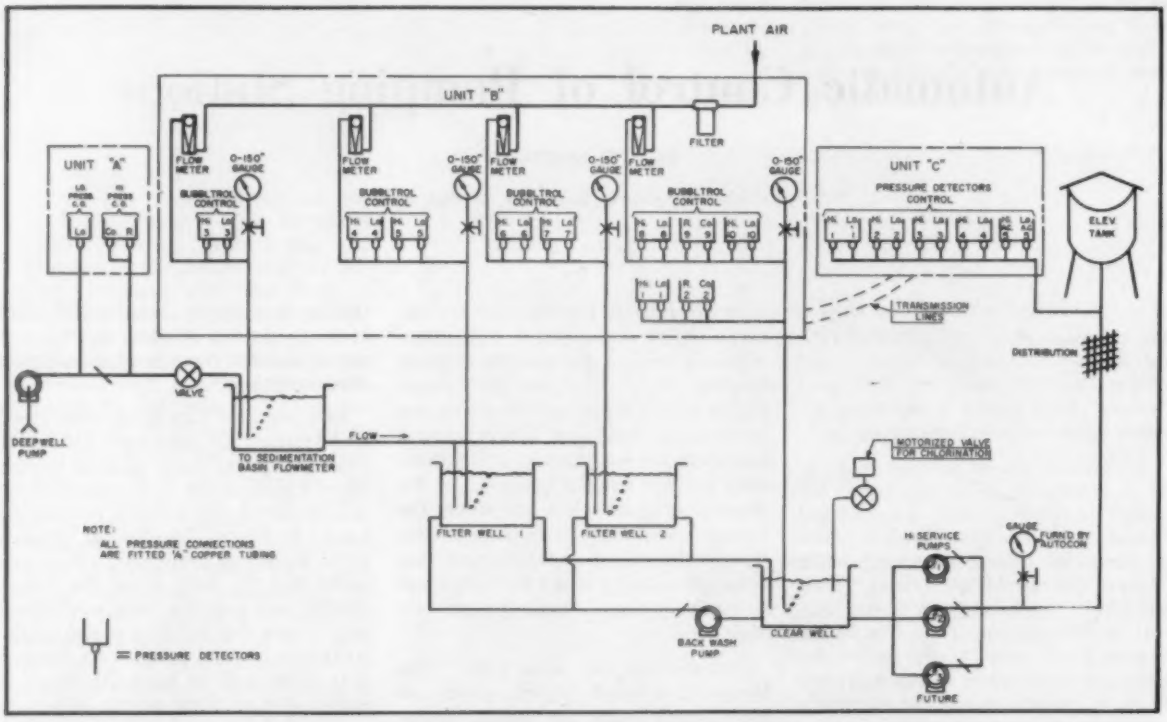
Is it simple? Can it be understood and serviced by personnel available? Does it require special skills or knowledge? (Most of the service work which will be performed is due to mechanical wear, therefore, mechanical moving parts should be minimized.) It is our belief that the odds favor the simple electric way over the older mechanical way. Were the builders proud of the workmanship and design? As a buyer, it is your right to have the detail to satisfy you on these points. When all is said and done, compare.

Were controls as common as automobiles, and was everyone experienced with controls as they are with automobiles, then, of course, no problem would exist. Unfortunately, there are very few real experts in the field today because to be an expert you must be exposed to the problem and acquire the experience factor which requires time and opportunity.

Automation vs Records

Possibly we should pause here and examine the matter of historical records. Industry today has become highly conscious of this subject. Many of us have found ourselves erecting high cost building to house what is more aptly named waste paper than records. Someone has a brainstorm to gather some statistics for some specific purpose, then when finished, forgets to turn the faucet off. Our company and others with which we are familiar, are scrutinizing these "records" as to intrinsic and permanent value. This does not mean we have discontinued record keeping, nor does it mean there are not those records which will be kept indeterminately, but keeping records for the sake of record keeping is out.

Water works men are faced with an identical situation. They must have records, but those records must provide vital statistics, otherwise, they are worthless. Records are not auto-



CONTROLLER integrates water system from raw ground water through all treatment stages to pre-use storage at midwestern community of 4000 population.

mation, records and automation are not synonymous and never will be. Automation is an immediate, dynamic thing. It is concerned with what is happening right now, the present. Automation anticipates and through anticipation is timely. A record is history. It is a history of something which has happened, not a warning it is going to. We learn from history and history is important.

Our company is not in the business of making records. Many of our system controls incorporate such devices where they are required in the system for the convenience of our customers. However, we do not manufacture these instruments. We buy them from specialists of long experience. Our company is concerned with and devoted solely to the manufacture of automation and control equipment, which is not synonmous with recording instrumentation.

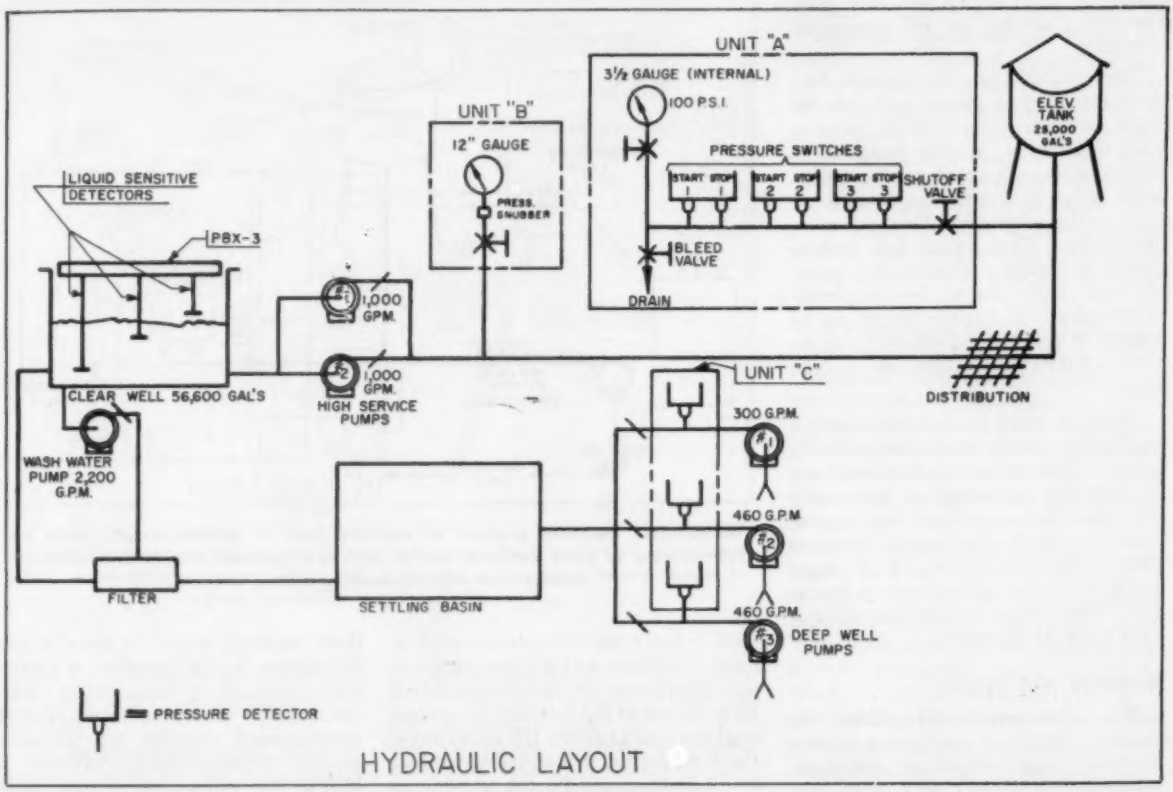
We believe that the record of a level in an elevated tank per se has little historic value. It provides no dynamic picture of the real conditions which exist in the system and is not worth the paper on which it is transcribed. This may startle some and is so intended. Knowing that there is pressure in the system, that it is adequate in high value areas, plus a true graphic picture of hour-to-hour, day-to-day operation is vital. It is the historical data from which any superintendent does his future planning, but we don't believe it is necessary to go out to the tank to determine that pressure exists. This intelligence is available anywhere in the system, and it also tells how much is in the tank, if someone is interested. In an emergency, the important factor is that the water is under pressure. It makes little significant difference whether this pressure is supplied by the tank or through pump action as long as the pressure itself exists. The fact the night of June 13th a tank held so many gallons has no significant historical value. The fact there was 80 pounds of pressure at Ninth and Main when the fire broke out is mighty important.

Pressure records on a system are of significant value but records from a point such as the tank which is the most stable point in the entire system may not be desirable or necessary and the transmission of such information may be even less necessary. A record of everything needed, plus additional benefits may be obtained at a key spot in the system, the pumping station or maybe elsewhere. Pressure recording at such points will give a truer picture of what is being delivered to the customer. At these points the operator can observe surges which rattle the pipes and the frictions which give a warning. In effect the operator's finger will be on the heart of the system; he will be able to see all the irregularities, he will see all the phenomena, and he will have a record which not only has historical value telling you many significant things but one which is intensely interesting.

Distribution System Control

From a control standpoint all distribution systems break into two broad classifications, primary systems and secondary or booster systems. The former refers to the system taking water from some natural source and delivering it to treatment, storage or use, or a combination thereof. The secondary or booster system is a localized improvement of a primary condition to increase pressure or flow, but with the source of water from a primary system.

Examining first the primary system, the problem is to deliver an adequate flow at a reasonable pressure from each and every tap in each and every section of the system, at every hour of the day and night, month in and month out. To accomplish this end there are



PRESSURE transmitter at tank operates high service pump at treatment plant plus high-low tank alarm. Probe type controls at treated water storage provide automatic low level cut-off for service pumps as well as high-low clear well alarms.

three classes of systems, the elevated tank system, direct pumping, or the tankless system, and on occasion the pressure tank system. This latter, though occasionally employed by municipals, is completely impractical from any standpoint when compared to either the elevated tank or direct pumpage. This leaves the two major types for discussion.

Reserve Storage

Most systems today use and store water which has been treated at least to some degree. Thus the present-day installations usually require an integrated system control, and often transmission of intelligence. Examining a control application, we start with the reserve in storage. This must be maintained at high levels. The important thing is to insist on measuring devices which do not rob the system of costly storage. It is better to make a number of measurements at definite points than a continuous measurement. There always is safety in numbers, hence multiple measuring devices, each transmitting its independent signal, are less apt to let the operator down than a single measuring element sending a single signal. In the latter case, if one is lost, all is lost; in the former but one of many is lost.

Measurements are directed to a high service pumping station or treatment plant. It is not uncommon, however, to have parallel or separate alarm signals transmitted to a secondary reception point such as fire hall or police station. The receiver picks up this intelligence, coordinates it to start and stop the necessary operation units required by the particular control scheme. These involve the high service pumps, valves, elapsed time meters, operations recorders or any other components.

It is important the devices be equipped with safeguards which will alert human operators in event of transmission line failure or failure of the control or operating equipment, or anything else which will hazard the operation. The primary consideration is to provide freedom for the operator so he can perform his more important tasks and leave the menial jobs to his control.

Any emergency arising in the system should be alarmed so the operator can move in and exercise judgment and decision. With proper automation no operator ever lives in a fool's paradise, thinking all is well when he is on the verge of a real emergency. Lack of such safeguards is pennywise and pound foolish. They are insurance. All good control systems have facilities for an operator to take over to manipulate the entire system on a supervisory basis. Simplicity is good design, and to maintain something it must be understood. A competent specialist can be of real service and save thousands of dollars.

Elevated Tank Systems

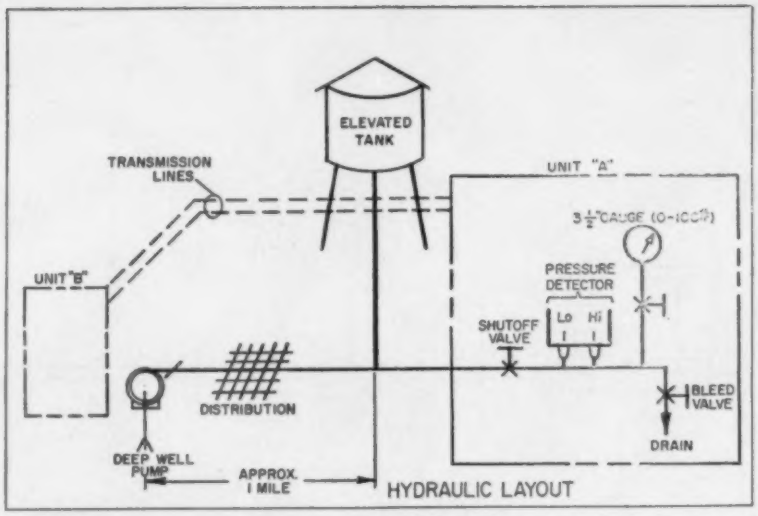
Starting with the most common, the elevated tank system, the basic unit is the single-pump, untreated or raw water installation. On this simplest of systems the problem of automation is equally simple. The system is supplied by maintaining the tank. This is done automatically by literally weighing the tank through measuring the pressure in the system. The tank is maintained as full as possible.

Naturally the simplest possible installation is always the most desirable. One easy rule of thumb is; with few or no users between the pump and tank, with the distribution lying beyond the tank, then a simple control installed at the pump house will be

eminently satisfactory and will give everything needed for full automatic operation.

Such devices can incorporate features for off-peak pumping or can include protective devices to protect your investment. Highly desirable to such a system is an alarm located at some point of continuous attendance such as the telephone office, police or fire station. This signals low system pressure through operation of an audible and visible alarm. In completely unattended localities this alarm can be a light or bell located where it can be seen or heard by residents who in turn report.

What is used in the more typical application where many consumers lie between? Sometimes such systems can be properly controlled as previously described and sometimes that type of control is wholly inadequate. It makes little difference whether it is single pump operation or multipump operation. The control on multipumping is only more of the same.



TRANSMITTER measures pressure at elevated tank to operate remote pump via telemetering to make optimum use of tank and maintain maximum reserve for emergencies with minimum operating expense.

Scattered Well System

For a scattered well system, the proper concept or perspective is very essential to understand the control and make simple devices do a really efficient job. This type of system has wells scattered throughout the distribution area. The important concept is the disassociation of certain pumps from the elevated tank. This idea involves one or possibly two pumping stations (essentially the ones nearest to the tank) having controls adjusted to maintain the tank within as close limits as practical without waste of power or hurting of the pump.

All other stations, with utter disregard for the tank level, have their control on a much coarser setting and one calculated for the immediate locale or area surrounding that station. In other words, it might be said each station is encircled by its own zone and the function of the control is to assume the pressure in its zone never falls below a given minimum and the pump is operated whenever necessary but never unnecessarily. Pressure limits are selected based on conditions in the zone and when the pump is in operation any unused surplus becomes available to adjacent zones.

Through coordinated control and studied pressure settings, coupled with adequate time delays, it is possible to provide a highly efficient operation in this type of system with some very simple controls. Each control is independent, no interwiring is necessary. The tank is maintained at a very high level because the controls are alert to local conditions and get the pumps in operation before the tank is diminished. Here is one of the benefits the control engineer can provide. He understands the fundamental principles with which he is dealing, and he can provide an effective, efficient control at minimum expense.

Direct Pumpage System

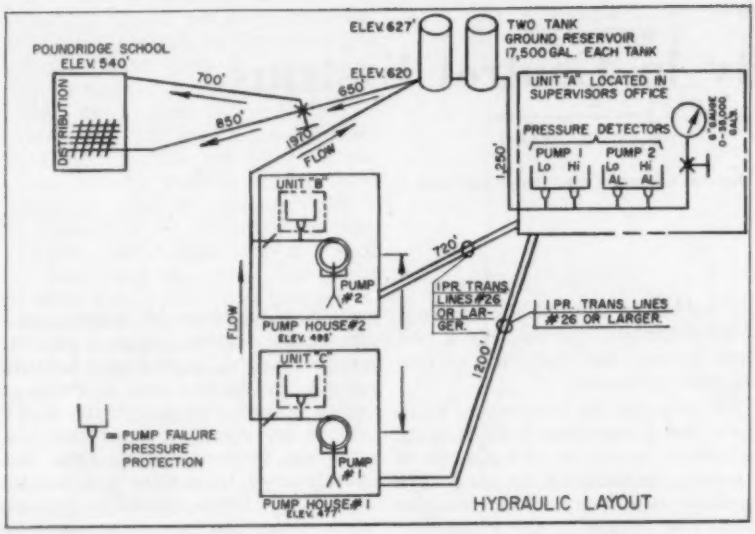
The second primary division of a distribution system is the tankless or direct pumpage system. This is not a new method, having been used industrially for many years. It has also been used on many municipal installations but generally has been restricted to the larger systems. While the system itself is not new, the techniques which make the operation efficient and automatic are not well known. This is no paradox but rather a reflection of the abundance of the past. Conservation was not so necessary. The cost of waste was not so high. The tankless system, properly understood and properly controlled, actually is the most efficient and most stable water distribution system in existence. The pressure holds within closer limits; it saves power; it is a tempered system.

The tankless system is ideally suited for emergency. Normal reservoirs are susceptible to normal catastrophe. The elevated tank is susceptible to tornado or explosive force. A ground reservoir or its connecting lines are susceptible to rupture. Both are subject to contamination. Were there no reservoir and only a subterranean supply pumped directly into distribution, there naturally would be standby motive power, hence a method of getting water from the ground source under the majority of circumstances. Natural underground supplies are protected against contamination by radiation. So long as there was a way of turning the pump you would have clean, sweet, usable and still 'willing" water.

The tankless system, by definition, is one with no storage reservoir or cushion tank for stability. Its total storage is the composite volume of the distribution piping. This is not true storage because it requires energy to use it. Were you to take a piece of pipe and entrap water at some hypothetical pressure, removal of a minute quantity would instantly dissipate the pressure. In effect, at one moment you could have a hundred pounds and a pin hole would plummet the pressure to zero.

The condition described could only be called highly unstable and yet the tankless system, which is merely a larger form of this concept, is highly stable and far transcends the average reservoir system in stability. The tankless system like any other to be efficient must be properly designed and properly applied.

Random selection of components can only yield lackadaisical, inefficient operation. Proper selection of components is pretty basic. Take pumps, for example. A pump that was highly efficient in a tank system might be worthless in a tankless system and vice versa. This could be said of virtually any component. Without question all units should be properly coordinated so that they complement one another



RESERVOIRS are maintained by set point pressure transducer located in supervisor's office. Transmitted signal to wells 1 and 2 operate pumps which return signals to report supervisory point via telemetering.

toward the total efficiency rather than fight each other and aggravate the inefficiency.

The tankless system works on a very simple principle. It uses the pump as a flowmeter and regulates the pumping to the flow requirements. It's really quite simple. Flow is measured by the pressure drop across an orifice. All pumps have a characteristic curve, one axis being head or pressure, and the other axis being flow. In a tankless system, through the pump, the pressure at any given moment has to reflect the flow at that moment. Just as with the flowmeter and its orifice, using the pump as our flowmeter, flow is being measured by pressure.

This works out with mathematical precision, in fact, to the point where with this type of system the control expert can sit down before the system is built, work out desirable characteristics, desirable pressures on a piece of graph paper, select components, work out a control, build it, ship it and install it with the end result corresponding exactly as calculated. And it doesn't take a mechanical brain or a computer circuit to accomplish this. It merely takes a few simple measurements and some very simple circuitry to do the job. It is done with the simple components of every day work; i.e., starters, circuit breakers, pressure switches, timers, transformers, relays, gauges and the like. The only really important thing is knowledge of the principles involved which again are quite simple.

Tankless systems range from a simple, single-pump application, boosting city pressure for a building on a part time basis, up through all types of industrial applications, housing projects, peripheral developments, primary systems and combinations thereof.

Many times tankless systems are superimposed on elevated tank systems and substitute for additional tank capacity. One extremely important point which can never be overlooked is the principles of control of a tankless system and a tank type system are completely incompatible. One, however, may be superimposed on the other, with the system normally operating on one set of principles and under emergency conditions, or through plan, transferring from the normal scheme to the secondary.

This operation can be explained by this example: Center Village set up housekeeping many years ago. It anticipated a normal growth, but some industry found haven there accelerating the growth and enticing more industry. Then there was a need for more storage capacity; the Village was at the end of its rope on pumping units, due to friction loss. The storage would be adequate if the total capacity of the tank could be held in reserve for emergency or outage, or even to alleviate an extreme low pressure condition in the high demand periods.

Many times in a situation as this it was possible to operate the water supply on a tankless system principle. Naturally the most desirable situation would be to never draw water from the tank except under emergency conditions. This poses the problem of stagnation. The solution is to run the system as a tankless system the majority of the time, say from 6 a.m. to 12 midnight, and then switch over to an elevated tank system. This recirculates the water keeping it fresh. With this type of operation there is always an emergency bypass which immediately transfers back to the tankless system operation and gets the pumps going should the tank drop excessively.

Normally only enough water would be taken out to keep the tank reserve sweet and clean, and the low limit or transfer point would be pretty high in the tank. Such a scheme automatically puts the tank on the system under outage conditions or any other type of emergency indicated by a subnormal pressure.

By these means does the village not only saves the capital investment of the tank but actually through power selection of pumps and proper automation, instead of the pressure extremes previously experienced, the whole system is smoothed out. It is stabilized and given a new lease on life.

Where conditions are extreme the control system can be worked out to permit a group of several smaller systems or secondary systems or any combination. There are many primary systems with secondary systems within the primary. The number of pumps is not important; the size of the pumps is not important; selection of pumps with proper characteristics is of vital importance. Planned control based on the proper principle is essential.

To recap, the tankless system is controlled from pressure. This pressure is derived from the pump and because of the pump's characteristics is indicative of flow. The pump is the flowmeter. There exists, in effect, therefore, balanced flow and pressure to create the ideal situation. We then hold that ideal quite closely through simple but effective control.

The key to success is the selection of components on a coordinated basis. The pumps cannot be selected with disregard for control principles nor controls with disregard to pump characteristics or system conditions. The entire distribution from source to use must be correlated, coordinated and controlled. This is true whether the control consists of a man pushing buttons or modern automation. The basic principles apply equally in both cases. Control systems and the principles on which they are based demand the services and cooperation of the experts in each and every field.

Simplicity in Control Systems

by C. S. BEARD

General Controls Corp., Hollywood, Calif.

IN THE FIELD of water treatment and distribution, use of instrumentation has increased rapidly. Through automatic control, quality has become more consistent. Analysis of distribution problems becomes easier with advanced logging techniques and more accurate measurement. Control systems can become complicated and will, of necessity become so, depending upon the amount and quality of the information which is required to carry on a successful and remunerative business. Nevertheless, simplicity in selection and design of control systems can save money. The simplest and often least expensive system may be best.

In many cases, the simplest method of controlling a system to obtain best quality and highest speed may turn out extremely complex. Tremendous numbers of control applications, however, may be handled best by a very simple approach.

Much unnecessary work and expense can be eliminated by using a simple device for a simple application. Most of us have seen control systems with embellishments for which the expense was not warranted—where a dependable automatic regulating valve might have handled the operation adequately and economically.

Distribution and conditioning of water lends itself to the simple approach more than many other processes such as the refining of hydrocarbons. This is because so many of the processes deal with pressure, temperature, and level as well as the more complex applications of flow control.

Nomenclature

A clarification of the nomenclature covering the instruments to be appraised is necessary, even though the units may be familiar to most of us.

The necessity of agreement in the use of terms which would seem to be self-explanatory becomes apparent in a recent discussion concerning the subject of this article. Sharp criticism came from an electrical engineer in the audience because of the use of the word "regulator" throughout the talk. It was only near the end of the evening that he realized that the regulator under discussion did not hold a constant voltage, but was used to control fluid pressure.

To preclude this occurrence, let us agree that a regulator is the simplest automatic device for the control of pressure, temperature or level. The regulator is a device which translates directly a change in the variable to be controlled into a corrective throttling action. In a pressure regulator, (Fig. 1) the controlled pressure creates a change in force exerted upon a diaphragm or piston to position a valve. In a level regulator, the main valve is positioned by the buoyancy of a float attached to a level arm. In the temperature regulator, the expansion of gas or liquid or the pressure created by an equilibrium between the vapor and liquid phases, supplies, in each case, the force to position the valve.

Ability of a pressure or temperature regulator to cause a corrective action is dependent upon the compression of an adjustable spring. Consequently, a finite change in the controlled variable is necessary before a change in the position of the main valve occurs. The sensitivity of this device is dependent upon the relationship between spring rate, diaphragm size, main valve size, and the unbalanced forces created by pressure drop across the main valve. It is the purpose of this article to present a few rules to follow in determining when this regulator may be used; but not to discuss the design or operation of the device.

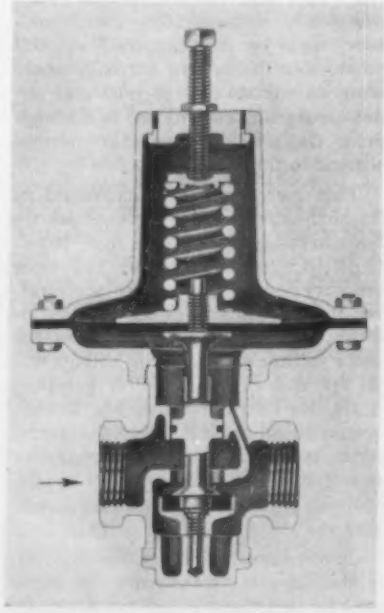


Fig. 1. SIMPLEST TYPE of pressure regulator may be entirely adequate.
(Courtesy Foster Engineering Co.)

Use of Pilot Regulators

A small pilot regulator may be used to cause movement of the main valve or the valve installed in the line in which the fluid to be throttled is flowing. This small pilot regulator may be made more sensitive than its larger brothers. This increased accuracy of control is mainly due to the very short movement of the diaphragm and small compression of the spring required to vary the extremely small fluid flow which occurs in pilot operation of the mainline valve. Innumerable systems have been developed to adapt the pilot to various control applications. These systems are based upon one of three approaches.

The first (Fig. 2) varies the pressure on the diaphragm of the mainline valve by maintaining a constant bleed from the diaphragm, but changes the supply pressure of fluid to the diaphragm with the small pilot regulator. In the second system. (Fig. 3), the supply rate is through a set restricting orifice, but the bleed rate is varied. The third system varies the pressure under the motor valve diaphragm by means of a pilot valve (Fig. 4) which loads or bleeds, depending upon its position. In each case, the pressure to the diaphragm is balanced by the line pressure to be controlled.

Electric or Pneumatic Control Systems

Bevond the scope for application of pilot-operated valves are control

problems which require pneumatic or electric control. In the pneumatic control system (Fig. 5), an instrument measures the variable to be controlled and puts out an impulse which varies as the measured variable deviates from the set point of the controller. To complete the control system, a valve or other control unit is positioned as dictated by this impulse. The control loop is closed by measuring the effect upon the variable that results from changes by the control valve or control unit.

When considering a control system, emphasis is too often placed upon obtaining throttling action using flow characteristics which are available, using various types of control valve bodies. In many cases, this approach is necessary but again for economy and simplicity on-off control should not be overloaded. This may be obtained with a simpler pneumatic valve or an electric valve (Fig 6.) Innumerable operations such as level control between limits, liquid transfer or charging, emergency shut-off filter backwash control, or orifice meter run selection may be handled in this manner. The electric system offers advantages when dealing with isolated tanks (no air is required), with simple limit controls, or when sequency of operations is involved.

With the regulator, the pilot-operated valve, or the control system at our disposal the question arises as to the best method to use to fit our needs and obtain adequate control in the simplest manner. It seems that the straightforward way to attempt this selection would be to explain the applications of the simplest method first and then move on to the more complex units. This was tried, but it was found that the better approach was to start the elimination process from the most complicated method and move on to the simplest. By this method, the operating conditions requiring the use of a controller are listed. If the desired application is not included in this list, the pilot system may be available. If the pilot system is not required, the regulator may be employed.

Controller Applications

Applications which require a controller are:

(1) When the variable to be controlled is other than temperature, pressure or level:

The control function must be preceded by measurement or evaluation. Variables such as pH, speed, gravity, heating value, flow, and others required in waterworks do not lend themselves to measurement by units which have the power to position a valve or control unit. Most of these applications are accomplished by varying the flow of some related medium which will change the measured variable.

Examples of these are: quality control where addition of chemicals is on the basis of pH, conductivity or turbidity measurement, backwashing which may be activated by abnormally high differential, or speed control obtained by varying fuel or steam rate to the prime mover. Most flow control applications using differential measurement require a controller to translate the small differential pressure to the force required to position a valve.

(2) When the valve of the variable to be controlled is beyond the range of a pilot system which may be used:

Generally speaking, the internally piloted piston-actuated valve will control steam pressures up to 600 psig, while pilot-controlled diaphragm-actuated valves will control

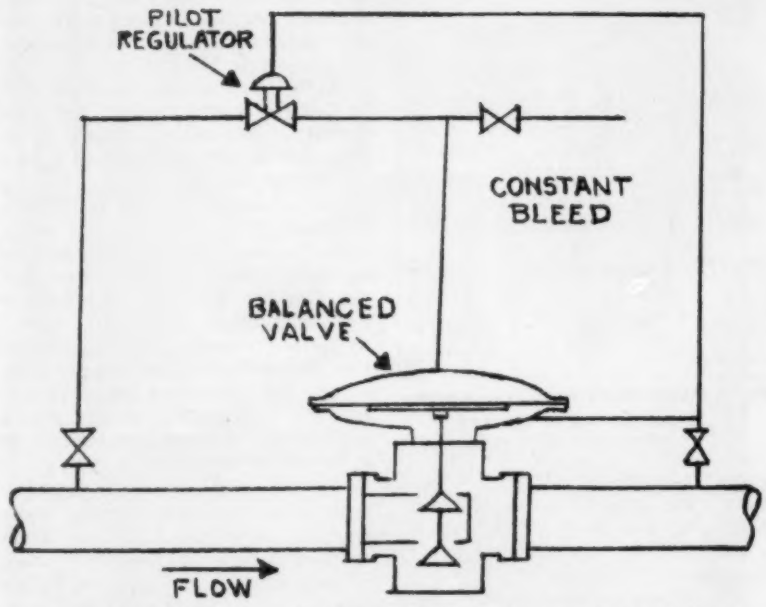


Fig. 2. PILOT REGULATOR positions line valve by varying supply to diaphragm

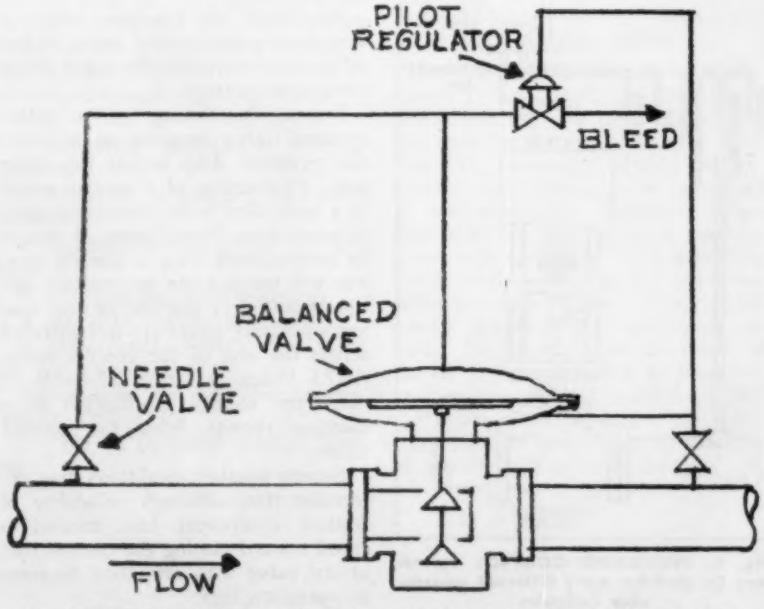


Fig. 3. PILOT REGULATOR positions line valve by varying bleed from diaphragm

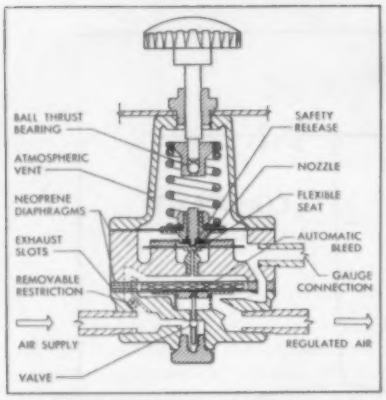


Fig. 4. PILOT VALVE will increase or decrease loading as required.
(Courtesy Moore Products Co.)

gases or water to 300 psig. Piloted valves are designed to control temperatures up to about 300° F. Use of a controller is indicated for applications above these limits.

(3) When the need is for closer control than is obtainable from a pilot system:

The pilot-balanced valve may be expected to control within one per cent of the controlled pressure setting. This is very acceptable for low pressure service; but inaccuracy of control becomes appreciable at high pressures.

Diaphragm-operated temperature valves in sizes up to 2 in. will control to within plus or minus 1°F. when the valve is used within its operating range. The piston-actuated valve is used for larger sizes; although available in sizes of 2 inches and smaller. This unit will control plus or minus 3°F.

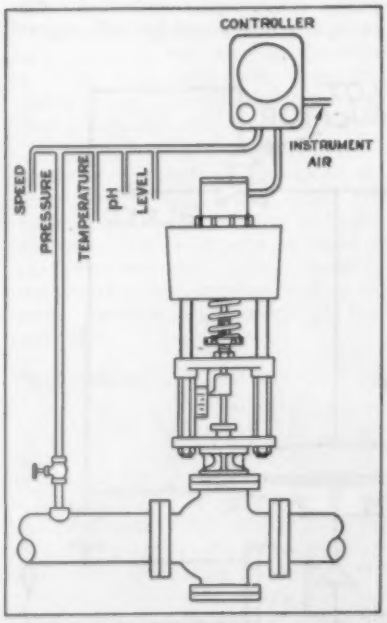


Fig. 5. PNEUMATIC CONTROL system may be used for many different measurable variables

Oddly enough, the limitation that requires a control system for level is not close control. Often, it is desirable to allow the level to fluctuate within the limits of a retaining vessel in order to obtain a steady rate of flow. This condition can occur when a surge tank is installed to absorb a change in influx rate and yet allow the affluent, which may be the flow through filters or softeners, to remain constant. To accomplish this, the controller must open or close a valve uniformly over a wide change in level. This gradual change over a wide range in many cases cannot be accomplished with a float pilot.

Control of level of an interface such as occurs when draining water from an oil or drip tank, is difficult without the use of a controller which in most cases is a displacement float type.

(4) When control application requires the available characteristics of a controller such as variable throttling range, automatic reset, or derivative action:

The pilot regulator is a low constant throttling-range controller without automatic reset or derivation action. These refinements become necessary when operational lags and operating conditions contribute to instability in the system.

(5) When need is for cascaded control:

In this form of instrumentation the output of one controller is used to adjust the control point of a second controller.

(6) When the available pressure drop across the control valve is insufficient to motivate the valve when using pilot control:

Proper functioning of a pilot-operated valve requires an appreciable pressure drop across the valve body. Positioning of a control valve by a controller is not dependent upon pressure drop. Nevertheless, it should be remembered that a control system will not operate successfully unless a sufficient portion of the system's pressure losses are concentrated across the seat of the control valve.

(7) When it seems advisable to place the control mechanism at a location remote from the control valve:

Severe weather conditions may determine this, although reliability of control equipment has created a trend toward placing the control unit at the valve with attendant decrease in operation lags.

Uses of Pilot-Operated Valve

According to recommended procedures, unless conditions requiring a controller exist, the pilot-operated valve should be considered. Operations to which this system of control may be applied are:

(1) When the variable is beyond the range of a regulator:

When the variable is pressure, the limit of application of a regulator depends on a combination of type of unit, static pressure and size of valve. In very general terms, the pilot-actuated valve becomes a consideration when set pressures exceed the following—

Gas	
Through 1¼ in.	250 psig
1½ in. and larger	125 psig
Steam	
Up to and including ¾ in.	275 psig
1 in. through 1½ in.	125 psig
Water	
Up to ¾ in.	3000 psig
Up to 2 in.	2500 psig
Up to about 8 in.	125 psig

Pilot-operated temperature regulators should be considered whenever the temperature range is less than 300°F.

Internal pilot-operated valves are widely used to control water storage tanks. Use of a pilot makes it possible to power the large line valves usually used for water level control in elevated water storage tanks. Various functions may be accomplished such as check valve, tank full and supply in which the same stand pipe is used, and differential level control.

(2) When it is necessary to hold the valve of the variable closer to a set point than can be done with a regulator:

A pilot system should control within approximately 1 per cent of the set point. This arbitrary figure depends upon the type and size of the regulator. As this deviation is a percentage rather than a constant, it becomes more of a grave consideration as the set point pressure increases. A balanced main valve will increase accuracy of regulation. The double-seated main valve may be used when lock-up is not required.

(3) When a characterized main valve is indicated:

Pilot operation, particularly in the piston-operated valve, allows for longer main valve travel. Although this travel is not as great as may be obtained with a control valve, it is sufficient for shaping the plug or ports to give various flow characteristics. Greater sensitivity of control

is possible with the characterized main valve.

(4) When greater facility for change in the set point from a remote location is desirable:

The spring and adjusting screw of the pilot may be replaced by a pressure chamber. The pressure in this chamber, which is the set point, may be varied quite easily by the use of a small regulator located on a control board.

(5) When no pneumatic supply is available:

The automatic valve of the internal pilot type (Fig. 7) uses line fluid to position the main valve. No gas or liquid bleed to atmosphere is necessary. This system may be used on toxic gases where even the small bleed of a controller nozzle cannot be tolerated. Isolated liquid and steam control systems may be handled with this type of valve.

Uses of Regulator

By this process of elimination, the pressure, temperature or level regulator is used when pilot system or automatic controller is not required. This would seem to relegate the regulator to a very insignificant role in the field of instrumentation. This is far from so—either numerically or functionally. To realize this it is necessary only to recognize the number of domestic water and gas regulators and the important part they play in daily life. An impressive list can be developed for determining when to use the pressure regulator as the correct method of control in water and sewage handling. These include:

1. All steam supplies to heating equipment.
2. Domestic regulators for water services.
3. Instrument and plant air systems.
4. Welding gas tank discharge.
5. Relief to suction on pumps.
6. Differential control for fuel oils and gland seals.

Applications for temperature regulators include:

1. Fuel oil or water storage heating.
2. Domestic and industrial water heaters.
3. Compressor and engine cooling systems.

Applications for levels are:

1. Cooling tower pit make-up.
2. Chemical mixing tank and boiler water storage make-up.

So many times the use of a regulator is not considered because it seems necessary to have closer control than the regulator will give. This "seeming necessity" should be examined very closely. It is important to determine truly whether a variation of a few pounds or a few degrees will contribute to a condition which is detrimental to the operation or to a quality of the product which would decrease its usefulness or value. So many times the value of the set point, whether it be pressure, temperature or level, is arbitrary and the limits of variation are also arbitrary and not based upon an analysis of the effect of a small change.

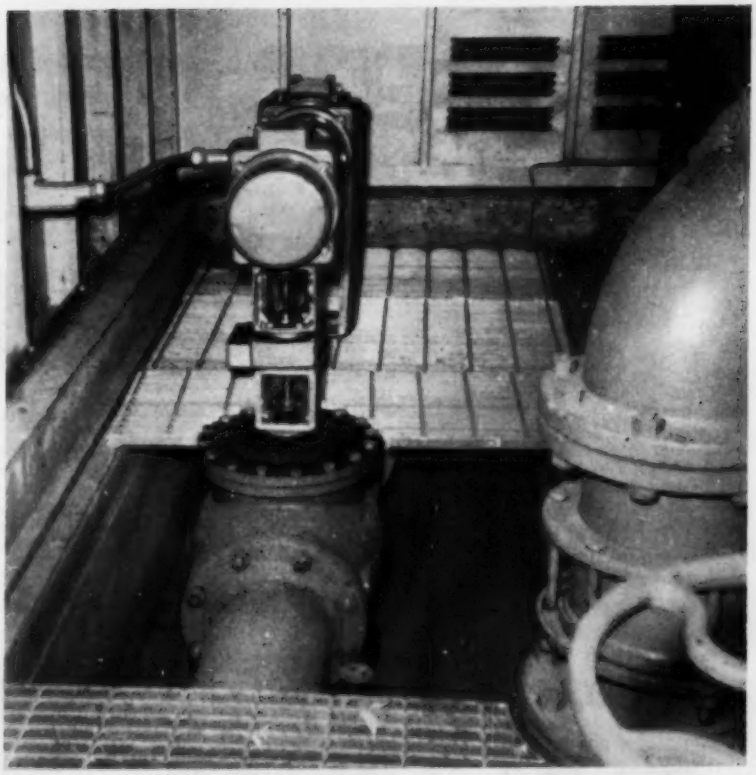


Fig. 6. ELECTRO-HYDRAULIC valve may be energized by emergency or control circuits.
(Courtesy General Controls Co.)

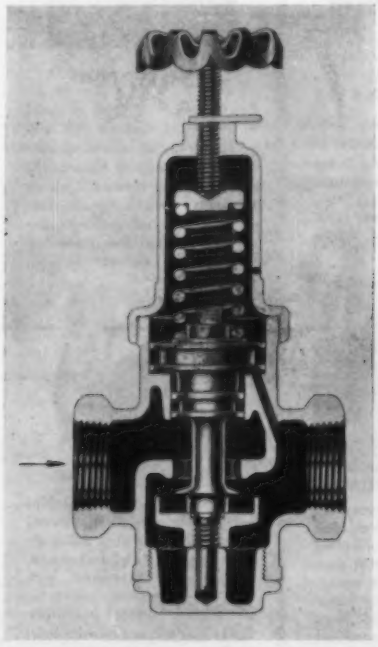


Fig. 7. SELF CONTAINED pilot system positions main valve by regulating pressure on balance piston.
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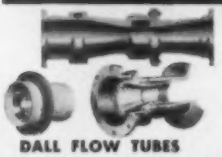

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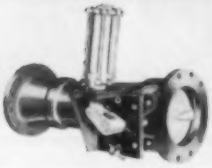

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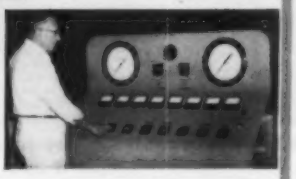

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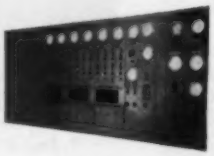

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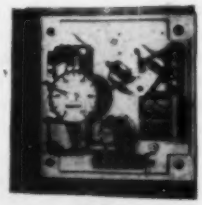

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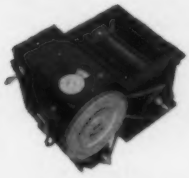

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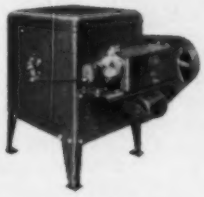

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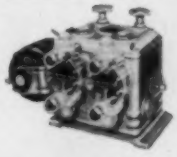

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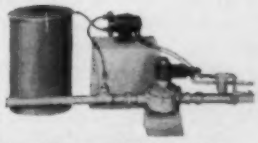

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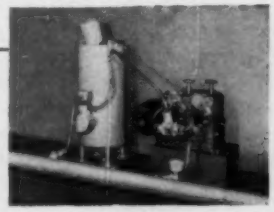

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CHEMICAL HANDLING AND FEEDING

WATER supplies which are not acceptable as is, for domestic consumption must receive treatment. In most cases treatment will involve the use of chemicals of some kind. Chemicals are also used in some types of sewage treatment, too, and in sludge dewatering and in sewage disinfection.

Coagulation of water or sewage may involve the use of aluminum sulfate, sodium aluminate, ferric sulfate, activated silica, and lime depending on the particular process used. Water softening will require lime, soda ash, and carbon dioxide. Disinfection will use chlorine, chlorine dioxide, or ozone. Taste and odor control may utilize activated carbon, chlorine, chlorine dioxide, and copper sulfate.

Sewage sludge conditioning generally uses ferric chlorine and lime but may use other coagulants (ferric sulfate, aluminum chloride, or aluminum sulfate). Industrial wastes may receive chemical treatment of diverse character depending on the waste being treated. Treatment may involve oxidation, reduction, chlorination, neutralization or coagulation, and may utilize other chemicals (sulfur dioxide, sodium meta-bisulfate, barium chloride, sodium sulfate, etc.) in addition to those chemicals mentioned above.

Whenever chemicals are employed in treatment processes, there also will be the problems of handling, storage and feeding.

Handling

Dry chemicals may be shipped in bulk, in paper bags of various sizes, in fibre drums or barrels of different sizes. The kind and size of container used will depend on the bulk density particle size, hygroscopic and chemical characteristics of the particular chemical, and I.C.C. regulations. Choice of container will also depend on the users' facilities for handling and storage.

Bulk chemicals may be unloaded into storage hoppers by air conveyors, tubular conveyors, bucket elevators and screw conveyors. Bags may be transported by hand trucks or on pallets. Drums, and barrels, are handled easily by hand truck.

Chlorine is shipped in 105 and 150 pound cylinders, in ton containers, or in bulk tank cars. Cylinders are handled by hand truck, ton containers by special lifting clamps and chain hoist. Liquid chemicals (i.e., ferric chloride, liquid alum) are shipped in tank truck or tank car.

Storage

Bulk dry chemicals are usually stored in hopper bottomed storage compartments from which they can be transferred to feeding devices. Packaged chemicals whether stored on pallets or not, generally require storage rooms, preferably above the elevation of the chemical feeders. This usually means that elevating equipment is necessary to lift chemicals from ground level to storage room. Storage should be fireproof.

Corrosive liquid chemicals are stored in rubber lined tanks from which they may be discharged to feeders by gravity or by air pressure. Chlorine containers are stored in a cool, dry, well-ventilated place away from heat sources, walkways, elevators, stairways and ventilating system intakes. Indoor storage should be above ground and fireproof outdoor storage should provide protection from direct sun, snow, and debris.

Feeding

The best installation for chemical treatment combines a simple mechanical feeding device, either liquid or dry feeder, with easy chemical handling and simple piping and injection or feeding arrangement. Chlorine is fed by a gas type feeder which dissolves the gas and discharges it as a solution.

Dry chemical feeders have four basic requirements: Accuracy, dosage check, protection against overfeeding, and efficient dissolvers. Dry feeders are of two general types—gravimetric, and volumetric. Gravimetric feeders have an accuracy (or uniformity of feed rate) of ± one per cent, and may be either loss-in-weight feeders or belt type feeders. Volumetric feeders have an accuracy of ± three per cent. The choice of feeder type depends on many factors including accuracy desired.

Solution feeders may be proportioning pumps, Rotodip feeders, or controlled outlet gravity feed. Solution feeders (except the Rotodip feeder) usually have feed rates of less than 57 gal per hr, but have extremely fine dosage control, especially in the proportioning type of diaphragm or constant controlled volume pumps.

Gas (chlorine, sulfur dioxide, or ammonia), is most conveniently fed in special solution type feeders, operating on a vacuum principle. Direct pressure type feeders are available, but are limited in application and not as fool proof and safe as are the vacuum type feeders.

In the selection of chemical feeder equipment it is essential to define operational equipment; determine the storage requirements; and choose the best available location, type of installation and type of feeder.

Materials for Handling

The type of material used for handling chemical solutions depends entirely on the characteristics of the chemical in solution. Corrosive solutions must be handled only in materials that are resistant to that particular solution. Among the materials used are stainless steel, rubber, Duriron, bronze, ceramics, asphalt, hard rubber, plastics, monel, nickel, tantalum, etc. The actual choice of material depends on the chemical involved. A tabulation of chemicals, their characteristics, feeding requirements, and suitable handling materials has been published as Keep Sheet No. 22 by B-I-F Industries, Inc.

Control

The type of control used in chemical feeder operation depends on the chemical being fed, accuracy of feed desired, size of installation, and the variability of feeding requirements.

Manual control equipment is put in operation and shut down, manually, by the operator and the rate of feed in lb per hr or lb per mil gal, is established by manual adjustment. Semi-automatic control or start-stop equipment operates at a rate manually pre-set but in step with pump or timed cycle. Paced proportional feed is accomplished through controls operated from flow measuring devices. Program control equipment provides automatic changing of the chemical feed rate throughout any period to follow changes in required dosage in accordance with a pre-established schedule.

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Rugged power . . . dependability and durability . . . combined with precise pumping accuracy can mean only Precision Chemical Pump's new Model S. "Straight-line" engineering — the most basic design to give greatest pumping efficiency — features a motor integral with gear train. Both operate immersed in oil within a tough, one-piece aluminum casing. Heavy duty plastic tubing and valve housings plus corrosion-resistant valves and metal reinforced diaphragm assure longevity of solution handling parts.

As versatile as it is rugged, the "S" will pump with extreme accuracy virtually all water conditioning chemicals: from hypochlorites and soda ash to nitric acid and alum.

Available in multiple heads and for sulphuric acid, all pumps are covered by a one year guarantee.

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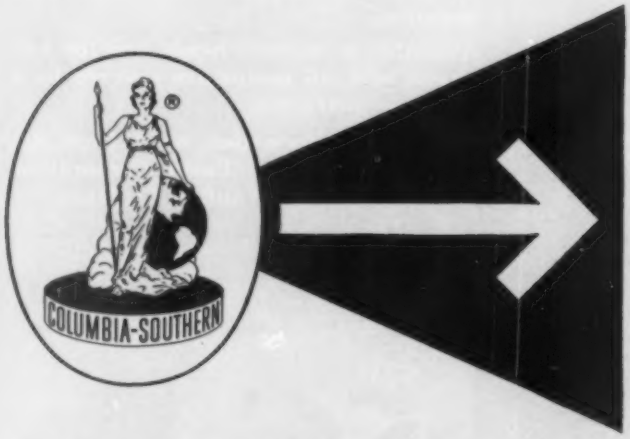

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In water supply systems, Pittchlor is used in the destruction of algae in reservoirs, the disinfection of distributing mains, the conditioning of filters, etc. Pittchlor's high stability also makes it an excellent stand-by product for emergency chlorination in the event of fire or flood, or when the water system has been contaminated accidentally.

In sewage treatment, Pittchlor's convenience and efficiency make it desirable for many uses, the major ones of which are: 1) to reduce Biochemical Oxygen Demand, 2) to suppress objectionable odors, 3) to disinfect effluent discharge, 4) to facilitate coagulation, 5) to meet the need for available chlorine in emergency purposes.

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Pittabs are packed in 3 lb. and 7½ lb. resealable cans and in 100 lb. drums.

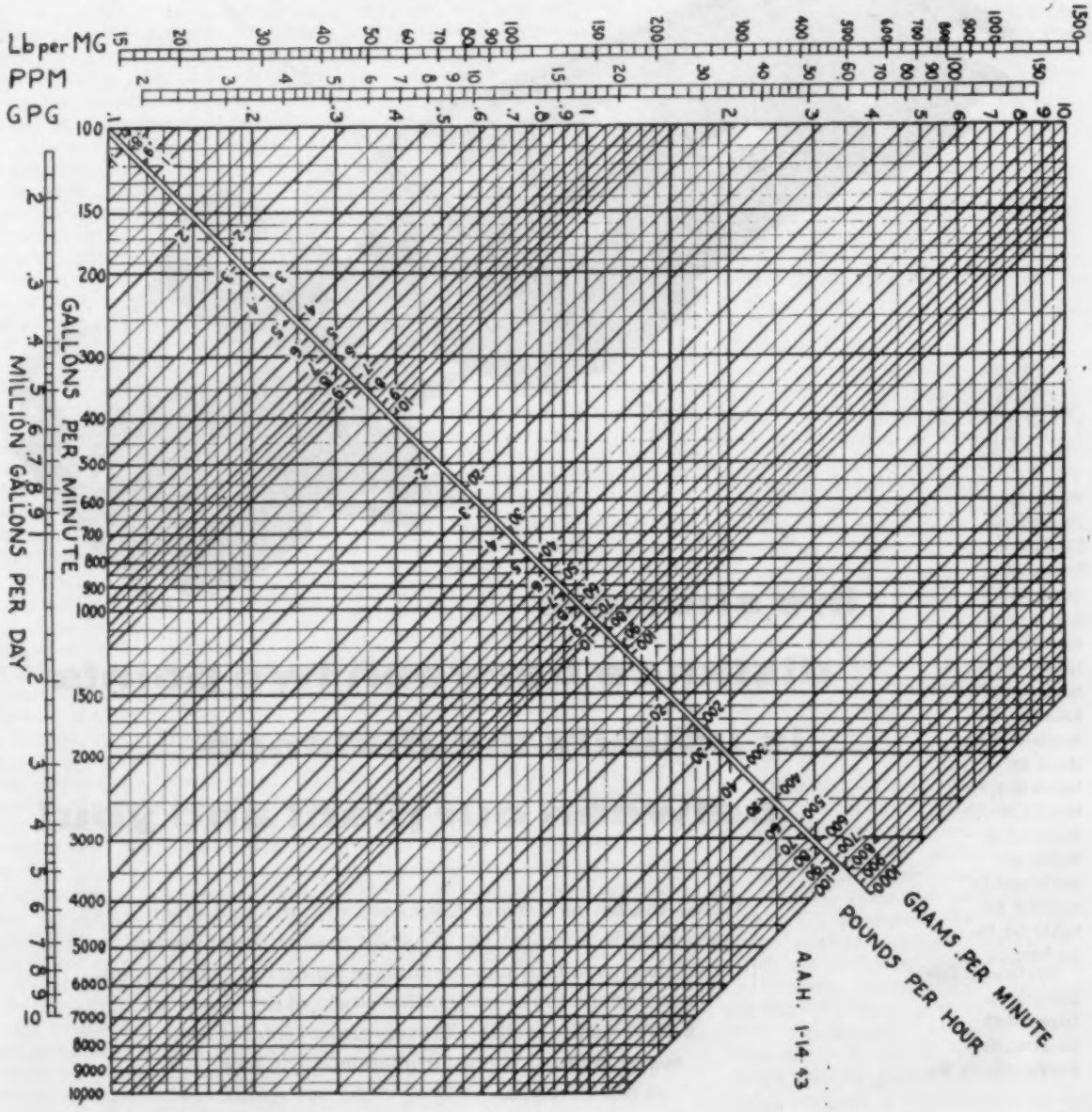
For further information on any of these products, please contact the Pittsburgh office or any of the branches.

For details circle 511 on inquiry card

Checking Chart For Dry Chemical Feed Machines

By A. A. HIRSCH

State Department of Education, Baton Rouge, Louisiana



The chart shown herewith offers a convenient means to check on the delivery of dry feed machines when the pumpage rate and the desired dosage is known. Rate of feed is expressed in grams per minute to enable weighing a timed discharge to check the feeder setting, and in pounds per hour to figure quickly the quantity needed in the hopper for each expected hour of operation. Chlorine dosage may be read knowing the change in platform scale readings per hour and the flow.

Parallel scales along each axis allow rapid conversion from one system of expression to another. On the vertical axis grains per gallon, parts per million and pounds per million gallons are quickly related by scanning directly across the scales. Gallons per minute and million gallons per day are similarly converted along the horizontal scale. In the plot grams per minute and pounds per hour are interchangeable across the diagonal scales. Pounds per hour is more logical from an operator's viewpoint than pounds per day. Many small plants operate only part of a day, or have a limited number of pumping steps, in which case pounds per day is merely a bookkeeping quantity.

A wide range in coverage is provided by the logarithmic divisions. High values not included on the chart may be read by using a tenth or hundredth of the quantity and applying the corresponding multiplier to the reading.

Example. How many grams per minute must be discharged from a dry feeder to give a 2 grain per gallon dosage while operating a 300 gallon per minute system?

Solution. Find the point where the 2 grain per gallon line and the 300 gallon per minute vertical intersect. This point lies between the 35 and 40 gram per minute diagonals at about 38 grams per minute. By projecting this value across the diagonal scales the hourly chemical consumption of 5.0 pounds is read.

When the answer falls in the area occupied by pounds per hour diagonals readings are converted to grams per minute by projecting in the same manner across the oblique scale.

When a metric scale is unavailable grams per minute may be obtained directly by catching the dry feeder discharge for 170 seconds and multiplying the weight in ounces by 10.

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Check the list of General Chemical's dry or liquid alum producing locations at left. Chances are one is convenient and close to you. In addition to these plants, our chain of warehouses across the country makes stocks of dry aluminum sulfate readily available in every major center of commerce. Write or phone for information on how we can serve you.

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COAGULATION AND SEDIMENTATION

THE PRESENCE of turbidity, suspended matter, bacteria or other organisms in water makes it unfit for domestic uses. Removal of the undesirable constituents is one of the purposes of water treatment plant. In sewage treatment the removal of suspended matter is essential to reduce the nuisance characteristics of the sewage. The unit processes which remove these undesirable substances from liquids are coagulation and sedimentation. In most water works, coagulation and sedimentation go together. In sewage works, sedimentation without coagulation is the usual practice, except where chemical treatment is used.

Definitions

Coagulation is the addition of a chemical to water or wastewater, whereby it reacts with other chemicals in or added to the liquid. The result is floc, which, by nature will enmesh and "sweep out" settleable, non-settleable, and colloidal matter in the liquid.

The chemicals used, called *coagulants,* must be carefully added in correct amounts; this is known as *dosing.* After addition of the coagulant, it must be thoroughly and quickly dispersed throughout the liquid being treated; this is known as *mixing,* and is accomplished by stirring devices. Following dispersion of the coagulant, the liquid is slowly stirred while the flocs grow in size and pick up impurities; this is called *flocculation.*

Sedimentation is the process by which the influence of gravity causes particles of suspended matter, and flocs to settle out of slowly moving or quiescent liquid. The rate of movement of the liquid must be slow enough to prevent the settled matter from being picked-up or resuspended by scouring action. Sedimentation is sometimes called clarification, but clarification generally refers to the combination of coagulation and sedimentation when both are employed.

Coagulation

The function, theory, control and operation of the coagulation process is the same for water and sewage treatment and the choice of coagulants may be the same, although some water and sewage plant operators have preferences in coagulants.

Most popular coagulating agents are the salts of aluminum and iron. Aluminum sulfate, generally called "filter alum", is generally used for water treatment. Ferric sulfate has been used for both water and sewage treatment. Ferrous sulfate (Copperas) can be used in water treatment with lime; it is not used in sewage treatment. Chlorinated Copperas is a mixture of ferric sulfate and ferric chloride produced by the addition of chlorine to ferrous sulfate on the site. Ferric chloride is used as a coagulant in the dewatering of sewage sludge for vacuum filtration. Aluminum chloride has been used for sludge dewatering where it is available as a waste material.

As aids to coagulation, other chemicals are sometimes added. One of the most effective is activated silica, produced at the site from sodium silicate and an activating agent such as chlorine, alum, carbon dioxide, sulfuric acid, etc.

Factors which influence the coagulation of turbid and colored waters includes: kind and quantity of coagulant, amount and character of suspended and colloidal matter, pH of water, mixing and flocculation time, liquid temperature, violence of agitation, presence of nuclei, etc.

The application of the correct amount of coagulating chemical is done by chemical feed machines, which may be controlled manually, automatically or paced by the flow of liquid. Determination of the proper chemical dosage is done by coagulation control tests, commonly called jar tests.

Sedimentation

The theory of sedimentation, is that under the influence of gravity, particles heavier than water tend to settle downward at a rate which depends on their size, weight, shape and on the resistance, or viscosity, of the liquid.

The purpose of sedimentation tanks is to remove as many settleable particles as is possible in the time available. To accomplish this, tanks are designed to produce the lowest possible rate of flow through the tank during the period of sedimentation. The shape of the tank may be circular or rectangular and depths may vary according to designers' preferences. Rate of flow through the tank, or the overflow rate, is based on the size of the particle to be removed in the time allotted.

Some tanks, particularly for use in water softening, called upflow-clarifiers, utilize vertical up-flow, usually through a sludge blanket at the bottom. These tanks combine the process of coagulation, flocculation and sedimentation all in one unit.

According to the theory of sedimentation, a particle settles according to its size and specific gravity. That fact can be made us of by controlling the velocity of flow so that heavy particles, such as sand, grit, etc., will settle out while lighter organic particles will be carried on to be removed later in sedimentation tanks. The design of grit chambers is based on this principle of differential sedimentation.

Sludge Removal

Wherever there is sedimentation the mass of solids removed is called sludge. Sludge, whatever the kind (coagulation, water softening, raw sewage, or activated sewage) must be removed from the sedimentation tanks. To accomplish this removal, many modern sewage and water plants use continuous sludge removal by scrapers. These scrapers operate continuously or on a timed cycle to move the sludge to a single sump, from which it can be pumped to a sludge disposal point. The design of sludge scrapers is directly related to the shape of the sedimentation tank. Some sedimentation tanks, the Imhoff tank for sewage treatment, and the upflow clarifiers utilize hydraulic transmission of sludge from sludge storage hoppers to point of disposal.

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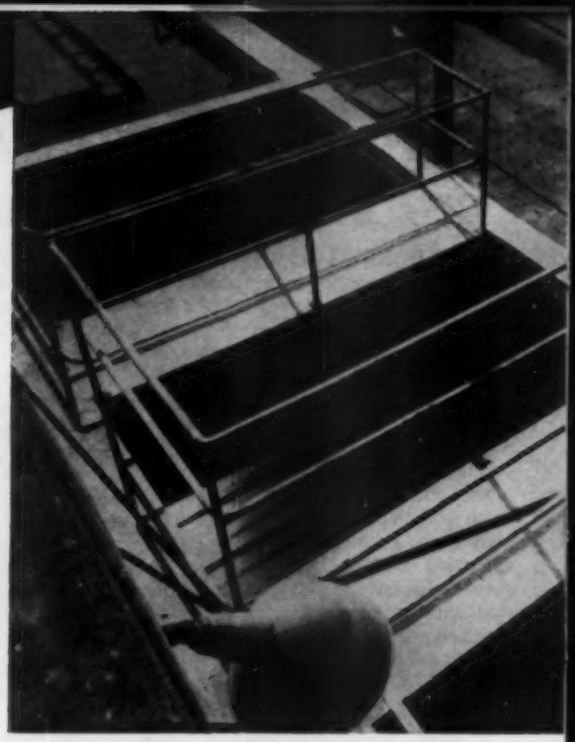
the Complete Line of Graver Municipal Water Conditioning Equipment



Graver designs and manufactures a complete line of water conditioning equipment to fit the needs of every municipality, large and small. Included are Reactivators, Conventional Conditioning Plants, Iron-Removal Plants, Filters, Zeolite Softeners, Aerators and all accessories. These units are the result of Graver's 50 years' experience in the treatment of water for municipal use. They are engineered for high operating efficiency, long-life service and dependable, trouble-free performance. A worldwide record of successful installations has proved the quality of Graver equipment.

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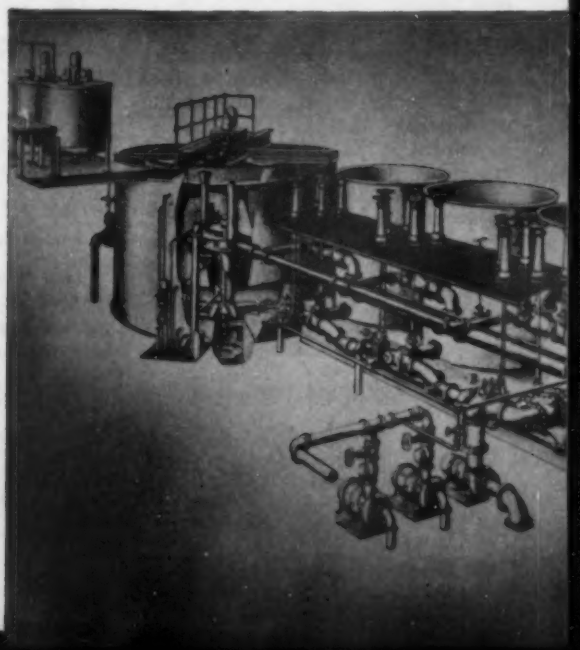

WRITE FOR ILLUSTRATED, DESCRIPTIVE BULLETINS containing detailed information on Graver equipment for municipal water treatment.

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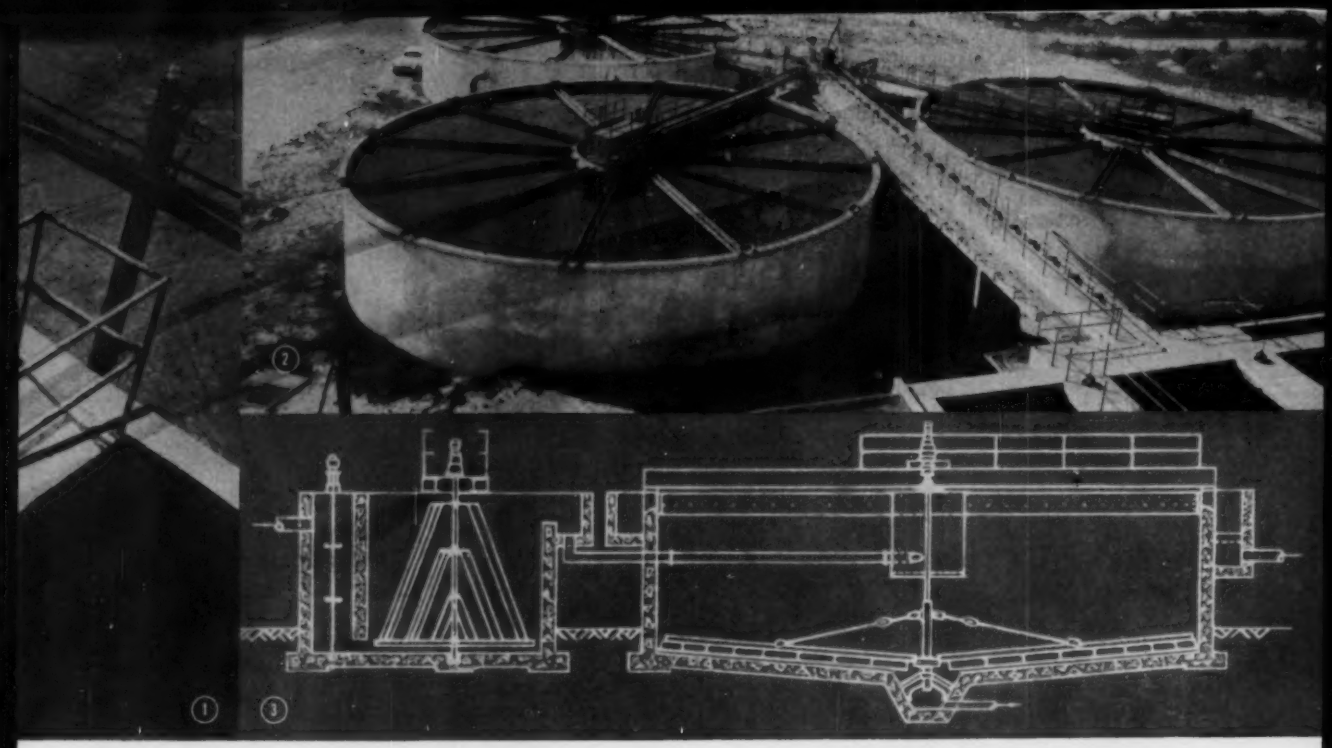

REACTIVATORS®

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The Graver REACTIVATOR produces treated water of the highest quality in minimum time and space. A high-rate, solids-contact, up-flow unit, it performs all the functions of coagulation, flocculation, sedimentation and sludge removal in a single compartmented tank. Exclusive **surgeability design** lessens carryover danger. Separately driven sludge scraper removes sludge over the entire bottom area.

2

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Rota-Rake® Sedimentation **Basins** — providing sludge removal over the entire bottom by revolving or chain-type scrapers.

Spirol-Mix Flocculators — designed to eliminate short-circuiting and to assure rapid floc formation.

Flash Mixers — providing rapid and thorough mixing with minimum power.

3

INTEGRATED TREATMENT PLANT

for the smaller community

Graver's integrated treatment plant with all necessary components and auxiliary equipment is designed to meet the needs of smaller municipalities. Included are the Graver Reactivator, clearwell, chlorinator, chemical feeders, gravity or pressure filters, piping and accessories. All the units are designed to work together for optimum efficiency and economy.

4

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Graver provides equipment for **seven** different methods of iron removal, including aeration (coke tray, slat tray, forced draft or closed pressure-diffuser) followed by filtration, sedimentation or clarification; ion exchange; internal or external aeration followed by clarification in Graver Reactivator. This wide selection assures the best method for each individual installation.

5

ZEOLITE SOFTENERS

When clarification is not a basic consideration, economical softening is obtained with Graver Zeolite Softening Systems. Their relatively low initial cost and simplicity of operation make them ideal for smaller communities. They are available in a wide range of types and sizes with either manual, semi-automatic or fully automatic controls.

6

BOILER FEEDWATER TREATMENT

For the municipality planning to build its own steam power generating station or to expand its existing facilities, Graver offers a complete line of feedwater softening and deaeration equipment—

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- Demineralizers
- Deaerating Heaters
- Hot Process Softeners
- Continuous Blowoff Systems

IN ADDITION TO BASIC EQUIPMENT, GRAVER FURNISHES ALL REQUIRED ACCESSORIES FOR WATER TREATMENT PLANTS

Activated Silica COAGULANT AIDS

PQ's N SODIUM SILICATE

Photograph—floc formed with aid of activated silica sol.

RAW AND WASTE WATER TREATMENT

Activated silica (made from N sodium silicate and a reactant chemical) used with a regular coagulant forms larger, denser, stronger floc and at a faster rate than when the coagulant is used alone. Floc enmeshes more impurities and suspended matter and settles out rapidly to produce clear, sparkling water. Treatment is effective with a wide variety of waters and in all popular flocculating and sedimentation equipment.

Activated silica sol is a dilute solution of sodium silicate, reacted with acids or acid salts such as sulfuric acid, carbon dioxide, ammonium sulphate, alum, chlorine, sodium silicofluoride or sodium carbonate. Four of these employed in the N-Sol Processes, outlined below, were developed by us and are licensed without royalty.

Preparation of the silica sol is done at the plant where it is used. Introduction into the water system can be made either by the "batch method" or by proportioning devices some of which continuously and automatically mix and feed the activated silica sol.

PQ ASSISTANCE

Samples of N sodium silicate (41° Baumé, 8.9% Na_2O, 28.7% SiO_2) and directions for making jar tests are available on request. PQ engineers are glad to share their knowledge in the use of activated silica sol to improve water quality. Ask for free literature, #52 series.

Sodium silicates are used also for controlling corrosion in water systems. *Further information on request.*

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	N-SOL-B (U. S. Pat. 2,310,009)	alum	Reactant readily available, inexpensive.
WASTE WATER Recovers reusable solids Prevents stream pollution Clears effluent	N-SOL-C (U. S. Pat. 2,567,285)	chlorine	Reactant usually available where sterilization is normal practice.
IN SUCH INDUSTRIES AS: Paper Petroleum Metal Finishing Plating Food Textile	N-SOL-D	sodium bicarbonate	Used where an alkaline salt is desired. For boiler feed water where ammonia is not desired.
	SULFURIC	sulfuric acid	Used where sol of low alkalinity is desired.
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Liquid Alum as a Coagulant

by R. W. OCKERSHAUSEN

Technical Service, General Chemical Division, Allied Chemical and Dye Corp., New York, N. Y.

EDITOR'S NOTE: For a water works man employing coagulation here are the answers to a number of questions he may have about liquid alum: What is it? Where is it used? What is its availability? How should it be stored and handled? How is it used? How does it compare costwise with dry filter alum? etc.

■ A CENTURY OLD CHEMICAL has "gone modern." Indeed, it "went modern" twenty years ago, when shipment in quantity began of commercial aluminum sulfate in concentrated liquid form. Aluminum sulfate is used by two large groups, namely paper mills which take about seventy per cent of the tonnage, and water works which consume the balance of about thirty per cent.

Plants for making liquid aluminum sulfate can be located only where a large "local" consumption exists. Paper mills concentrate in well defined areas and provide the sizable tonnage needed to justify alum producing facilities. Water works, though smaller users, when near these facilities are able to take advantage of this product.

"Dry alum," "filter alum," or "paper-makers alum," as it has been called, has been supplied to water plants and paper mills in slab, lump and ground forms. Solutions of alum have been used for decades; these were made by dissolving the slabs or lumps in suitable tanks to strengths usually of five to fifteen per cent. In contrast to these weak solutions, laboriously made at the point of use, commercial liquid alum is now being shipped at nearly fifty per cent strength. Where consumers are within a reasonable shipping distance, liquid alum can be attractive financially, will reduce handling and labor costs, will promote plant cleanliness, conserve space, and contribute to employee safety.

What Is Liquid Alum

Aluminum sulfate is made by reacting bauxite or high alumina clays with sulfuric acid and water. After the reaction the liquors are treated in various ways to reduce impurities and insoluble material. Evaporation of excess water results in a syrup which when cooled, solidifies into a cake or slab form. Grinding the cake produces the material with which most plants are familiar. The dry product has the formula—$Al_2(SO_4)_3 \cdot {}_nH_2O$ in which the "n" is approximately 14. The 14 molecules of water of crystal-

IN 20 TO 40 MINUTES, this 4000 gallon tank truck can be unloaded at a water purification plant

Fig. 1—PRINCIPAL liquid alum producing plants in the U.S. and Canada.

lization give a dry product with 17 per cent Al_2O_3 content.

By certain steps in manufacture, the liquors can be controlled at approximately 8.3 per cent Al_2O_3 which is close to a fifty per cent solution of the dry alum. Liquid alum differs from dry alum only with respect to its water content. The paper plant and water purification processes are not changed by the form of the alum; only the facilities for handling the liquid form differ.

Availability—Where Manufactured

Tonnage demands for aluminum sulfate have steadily increased with the expansion of the paper industry and the enlargement of water purification plants to care for the growth in population. Paper mills tend to concentrate in some seven or eight geographic areas where water, raw materials and transportation are available. To better serve these large users, approximately forty liquid alum manufacturing plants have been located in those areas.

Figure 1 shows the location of a number of the present plants. As numerous as the alum plants are, it is obvious that there are areas where liquid alum is not available, and will not be available until a greater consumption warrants a producing installation.

In general, it is uneconomic to ship liquid alum more than 100 miles; the reason is the necessity of paying freight charges for two tons of liquid product, which is the equivalent of one ton of dry alum. Added to the double freight charge is the necessity of tank-trucks or tank-cars returning to the producing works empty, that is, without a payload.

Advantages in a lower base cost of the liquid alum are offset when long hauls are involved. A study of dry versus liquid alum freight rates may indicate that the longer haul for liquid alum can be justified, if the producing location for dry alum is remote and a high tariff exists.

Who Can Use Liquid Alum

Liquid alum should be considered whenever a new water plant or paper mill is being designed. It is cheaper and simpler to design for liquid storage tanks before plants are constructed, than to make the conversion in existing plants. In a time of ex-

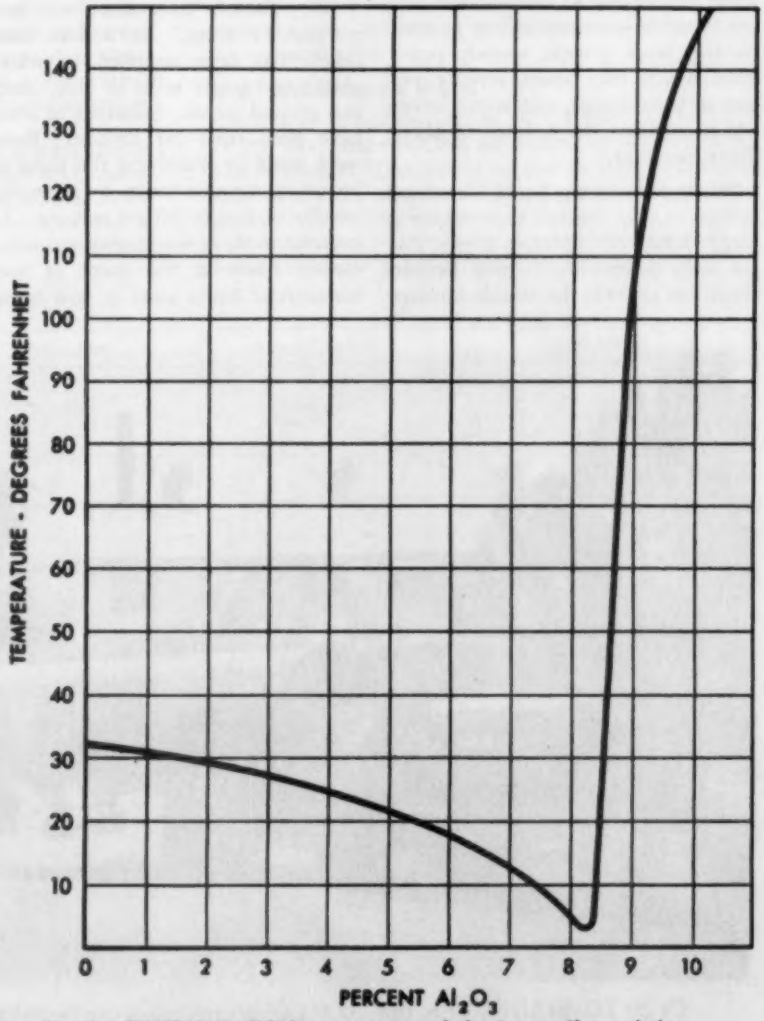

Fig. 2—CRYSTALLIZATION temperatures of aluminum sulfate solutions.

pansion and modernization, liquid facilities can be planned for, if chemical rooms and feeding equipment are part of the expansion.

When chemical feeding equipment is to be retired because of age, the economics of new dry-feed equipment may be compared with a liquid alum storage and feeding set-up. Finally, in existing paper or water plants a liquid alum installation may be justified when the savings per ton are sufficient to amortize the tanks and feeders in a reasonable time.

Consumers of less than 100 tons of dry alum per year will not usually be able to discard dry-feeders, and justify the investment in liquid facilities (which may cost from $3,500 to $7,500 for minimum equipment). Some exceptions in smaller water plants deserve mention. In several instances dry alum was shipped a great distance and carried high freight charges. In these cases, when the lower base cost for liquid alum from a near-by source was considered, and the saving in freight was added, total savings in the order of $7 to $10 per ton (dry basis) resulted.

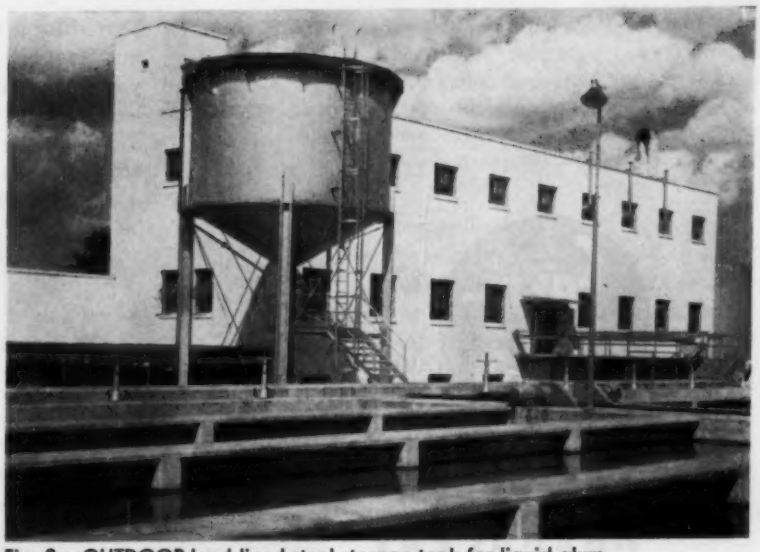

Fig. 3—OUTDOOR lead-lined steel storage tank for liquid alum.

Table 1
Characteristics of Aluminum Sulfate Solutions

				TEMPERATURE—60° F	
°Be'	Sp. Gr.	Lbs./Gal.	%Al_2O_3	Equiv. % Dry	Lbs. Dry/Gal.
1	1.0069	8.40	0.19	1.12	.09
2	1.0140	8.46	0.39	2.29	.19
3	1.0211	8.52	0.59	3.47	.30
4	1.0284	8.58	0.80	4.71	.40
5	1.0357	8.64	1.01	5.94	.51
6	1.0432	8.70	1.22	7.18	.62
7	1.0507	8.76	1.43	8.41	.74
8	1.0584	8.83	1.64	9.65	.85
9	1.0662	8.89	1.85	10.88	.97
10	1.0741	8.96	2.07	12.18	1.09
11	1.0821	9.02	2.28	13.41	1.21
12	1.0902	9.09	2.50	14.71	1.34
13	1.0985	9.16	2.72	16.00	1.47
14	1.1069	9.23	2.93	17.24	1.59
15	1.1154	9.30	3.15	18.53	1.72
16	1.1240	9.37	3.38	19.88	1.86
17	1.1328	9.45	3.60	21.18	2.00
18	1.1417	9.52	3.82	22.47	2.14
19	1.1508	9.60	4.04	23.76	2.28
20	1.1600	9.67	4.27	25.12	2.43
21	1.1694	9.75	4.50	26.47	2.58
22	1.1789	9.83	4.73	27.82	2.74
23	1.1885	9.91	4.96	29.18	2.89
24	1.1983	9.99	5.19	30.53	3.05
25	1.2083	10.08	5.43	31.94	3.22
26	1.2185	10.16	5.67	33.35	3.39
27	1.2288	10.25	5.91	34.76	3.56
28	1.2393	10.34	6.16	36.24	3.74
29	1.2500	10.43	6.42	37.76	3.93
30	1.2609	10.52	6.67	39.24	4.12
31	1.2719	10.61	6.91	40.65	4.31
32	1.2832	10.70	7.16	42.12	4.51
33	1.2946	10.80	7.40	43.53	4.71
34	1.3063	10.89	7.66	45.06	4.91
35	1.3182	10.99	7.92	46.59	5.12
36	1.3303	11.09	8.19	48.18	5.34
37	1.3426	11.20	8.46	49.76	5.57
38	1.3551	11.30	8.74	51.41	5.81
39	1.3679	11.41	9.01	53.00	6.05

NOTE: BASED ON 17% Al_2O_3 IN DRY ALUM (General Chemical Research Laboratory).

Such savings are unusual and they provided incentive for the smaller users in the area to convert to the liquid product. These users were able to write-off the investment in less than five years. To this category should be added the several plants with awkward handling problems and inadequate storage facilities. The cost of labor for unloading and transferring dry alum, together with some saving in the product, warranted changing to the liquid system.

Some efficiency-minded superintendents consider ease of handling so important that the convenience of handling alum in solution form has added incentive toward converting to the liquid product, when other conditions are favorable. This is one of many factors besides tariffs which must be considered at each location in determining the feasibility of liquid alum use.

Why 8.3 Per Cent Al_2O_3

Since shipment of any liquid product involves the payment of freight on water, it is desirable to save the consumer as much as possible, by shipping the product at the highest concentration that can be readily handled. This further makes for economy in

Ferri-Floc gives smoother, more efficient and trouble free operation. Whatever your particular water treatment problem may be, you can depend on Ferri-Floc doing a superior job and doing it efficiently and economically—Ferri-Floc is a free flowing granular salt which can be fed with few modifications through any standard dry feed equipment. It is only mildly hygroscopic, thereby permitting easy handling as well as storage in closed hoppers over long periods of time.

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Fig. 4—DETAILS of piping and valves for liquid alum storage tanks.

keeping storage tanks to a reasonable size. A further consideration is the crystallization or freezing point of alum solutions.

Figure 2 shows that the freezing point is at its lowest at approximately the 8.3 per cent concentration. Trace impurities influence the freezing point, and values of 2°F to 18°F have been reported. For practical purposes, no freezing difficulties will be encountered if the product is stored according to manufacturer's recommendations. Feed-lines should be protected from unusually low temperatures. A concentration of 8.3 per cent Al_2O_3 has been used by most producers as a safe strength to ship.

Properties of Liquid Alum

Liquid alum of 8.3 per cent Al_2O_3 has a weight of 11.15 lb per gal. One gallon has the equivalent weight of dry alum of 5.4 lb. It is approximately a 48.5 per cent solution of dry alum. A rapid method of determining the approximate strength is by use of the Baumé hydrometer. The solution as shipped will test 36.4° Baumé. This is the equivalent of a specific gravity of 1.335. Table 1 gives the concentration of liquid alum for different specific gravities and Baumé readings at 60°F.

Liquid alum solution is acidic and has a pH value of 2.4. The viscosity at different temperatures is given in Table 2.

A typical analysis of liquid alum would be approximately as follows:

Total Aluminum Oxide, Al_2O_3	8.3%
Combined Aluminum Oxide, Al_2O_3	8.2%
Free Aluminum Oxide, Al_2O_3	0.1%
Total Iron, Fe_2O_3	0.2%
Insoluble Matter	0.05%

Method of Shipment

Tank-trucks of 2,000 to 4,000 gallons capacity are used for shipping liquid alum. The trend is toward 4,000 gallon stainless steel tank transports. In certain areas rail shipment in rubber-lined or stainless steel tank cars of 8,000 to 10,000 gallons capacity is used. In the case of tank-trucks, pumps or compressors are mounted on the producers' trucks for discharging to the consumers' storage tanks. Where shipment is by railroad, compressors supplying air at 30 pounds pressure are necessary at the receiving station for unloading the tank-cars. The time required for unloading a 4000 gallon tank-truck usually is from 20 to 40 minutes depending on the head. An accompanying photograph shows a typical tank-truck used in this service.

Storage Tanks

The largest single item in a liquid alum installation is the storage tank. The minimum size recommended is 6,000 gallons. This volume is approximately 1.5 times the size of the delivery trucks. Where tank-cars are involved a minimum size of 15,000 gallons is suggested. These are recommended minimums and where large tonnages are consumed, the storage equipment will be sized to hold at least 7 to 10 days supply, depending on the proximity to the producing location.

The space needed for liquid alum can be roughly calculated at 40 pounds (dry equivalent) per cubic foot. This value compares with approximately 60 pounds of dry alum per cubic foot. Bags of dry alum are seldom stacked more than 6 or 7 deep to facilitate both stacking and removal from the pile. On the other hand, tanks for liquid alum will use the same space from floor to ceiling, and greater utilization per square foot of floor space results. Where tanks are on upper floors the question of floor loading must be studied before liquid equipment is installed.

The location of storage tanks may differ between warm and cold sections of the country. The warmer climate in the south enables placement of tanks on the outside, while in colder climates indoor tanks are preferred. It is possible to insulate, and even to heat outdoor tanks in colder climates but this adds to the cost of the installation. Burial of tanks is not favored since it makes inspection and clean-outs awkward. Leaks are uncommon but they can not easily be detected in underground tanks until the losses are great.

Rubber-lined steel or wood, concrete, or steel tanks lined with lead are preferred. Rubber and lead have stood the test for twenty years, and maintenance on the linings during this period has been very low, and in some plants nothing. This fact does not preclude the use of newer self supporting plastic tanks, plastic linings, or plastic bag liners. Such are under test at the present time and it is possible

Table 2
Relation of Viscosity to Temperature

Baume Reading	Per Cent Dry Alum	Viscosity in Centipoises 40° F	60° F	80° F
8.3	10.0	2.4	1.7	1.3
16.1	20.0	3.2	2.3	1.6
23.7	30.0	4.0	2.9	2.0
30.6	40.0	17.5	10.5	6.7
36.4	48.5	43	26	17

the variety of satisfactory materials will expand with experience.

Unsatisfactory results with certain plastic liners were partly due to poor adhesion to the walls, the presence of pin holes, and in the case of one semi-rigid plastic tank to poor mechanical design of the seams. Such difficulties may have been overcome in the equipment now under observation.

Since liquid alum may be shipped as warm as 130°F, the effect of temperature and temperature changes over a period of time on the plastic must be determined. Unlined wood is being used and contrary to numerous failures of wood necessitating lead-lining, several plants report satisfactory results after approximately three years of use. Stainless steel (Type 316) tanks and a glass-lined steel tank

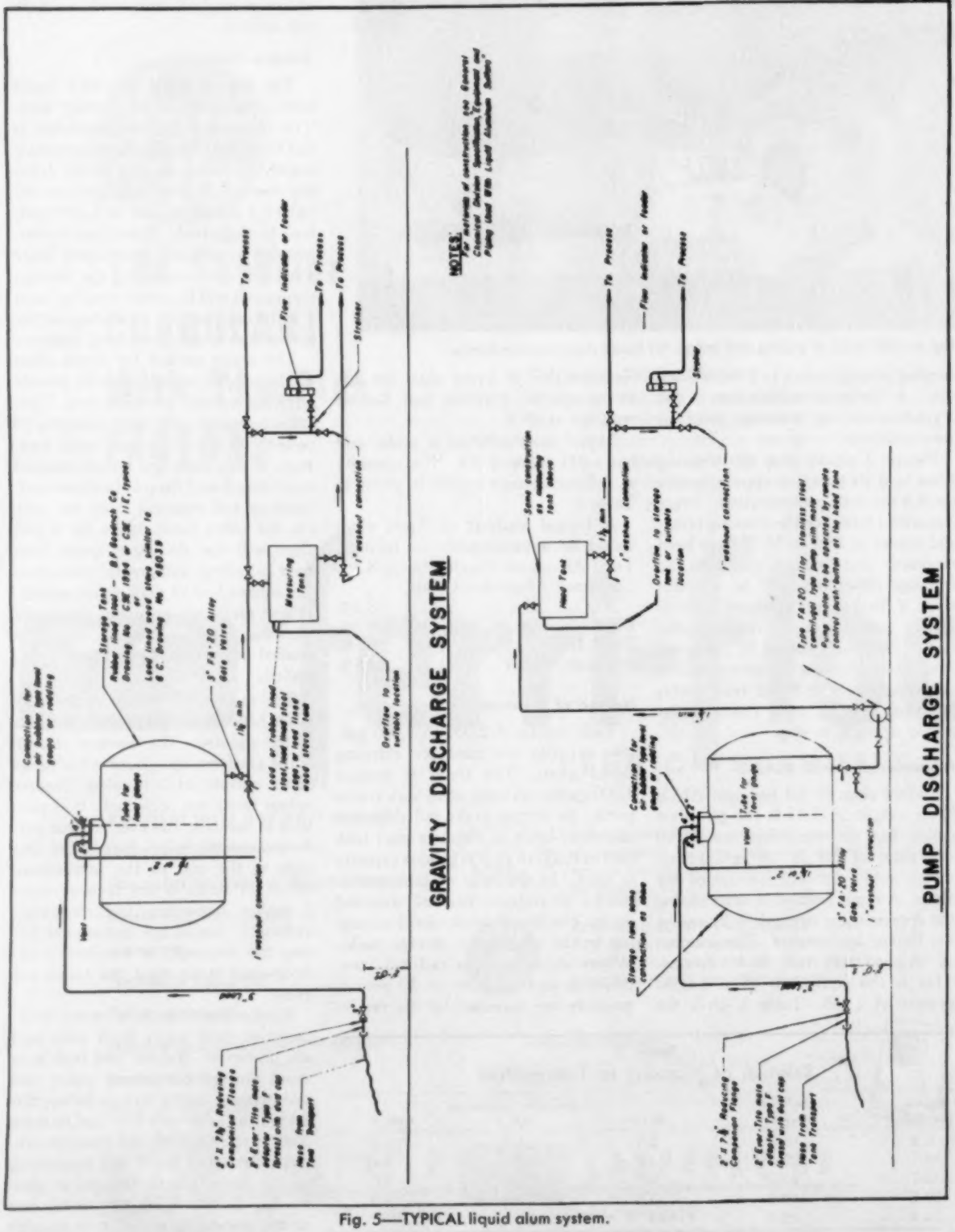
GRAVITY DISCHARGE SYSTEM
PUMP DISCHARGE SYSTEM
NOTES
To Process
Flow Indicator or Feeder
Strainer
Measuring Tank
Head Tank
Overflow to Storage
Overflow to Sanitary Sewer
1" washout connection
5" FA-20 Alloy Gate Valve
Vent
Tube for Level Gauge
Connection for Air Bubble Type Level Gauge or Reading
Storage Tank
Rubber lined steel - B.F. Goodrich Co. Drawing No. CSE 1594 or CSE 11/E, typical
Lead lined steel alloy similar to U.C. Drawing No. 49039
Lead or rubber lined steel, lead lined steel or wood tank
Some construction as measuring tank above
Type FA-20 Alloy stainless steel centrifugal type pump with motor. Pump motor to be operated by remote control push button at the feed room
5" x 2½" Reducing Companion Flange
2" Cast Iron male adapter Type F threaded with dust cap
Hose from Tank Transport

Fig. 5—TYPICAL liquid alum system.

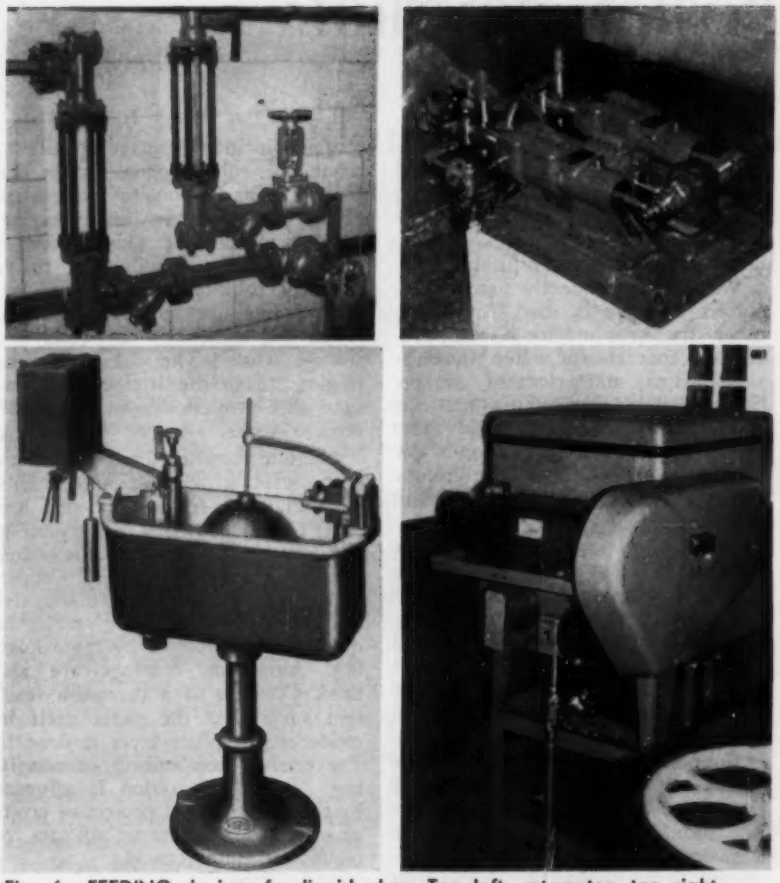

Fig. 6—FEEDING devices for liquid alum. Top left, rotameter; top right, proportioning pump; bottom left, constant head orifice box; bottom right, Roto-Dip.

are giving expected good service.

Figure 3 illustrates a 25,000 gallon lead-lined steel storage tank.

The lead used for lining tanks contains 4 to 6 per cent antimony and is of the "8 pounds per foot weight." Some large installations use "10 pound" lead. In the case of rubber-lined steel, the lining is approximately 3/16 inches thick.

Some plants install loose fitting plank covers for the lead-lined tanks and this reduces evaporation losses. Any loss of water from the liquor tends to produce a more concentrated solution at the surface, and increases the danger of crystal formation. Rubber or lead-lined steel tanks generally are closed. Closed tanks have vents in the top which extend over the side of the tank. When the tanks are equipped with bottom outlets these should be three inches in diameter to allow for easy flushing or cleaning.

Piping

Unloading lines should be 3 inches in diameter and made of antimony lead pipe with ¼ inch wall thickness. Lead pipe should be well supported to prevent sagging. Uscolite, Saran, hard rubber, rubber-lined steel and stainless steel (No. 316) are suggested for feed lines and these should not be smaller than one inch even in the smaller plants. Flush-out connections are desirable.

Valves

Rubber-lined diaphragm valves of the Saunders Patent type or renewable rubber liner valves give long service. Directly under the storage tank a 3 inch gate valve of stainless steel type FA-20 alloy is recommended. Figure 4 shows piping and valve detail in one plant.

Pumps

The manufacturer's tank trucks have pumps or compressors for unloading to the user's storage tanks. When the product must be pumped, as to a head tank, centrifugal pumps with wetted parts of stainless steel type FA-20 alloy should be used.

The manufacturers of liquid alum can supply information on tanks, lines, valves and pumps, and can provide typical prints as in Figure 5.

Feeding

A variety of feeding and feed-control devices are used for liquid alum (See Fig. 6). These include the Roto-Dip, rotameters, proportioning pumps, and constant head orifice boxes. Both concentrated and dilute liquid alum are being fed successfully with all of the feeding devices. They can be installed for manual operation or equipped for automatic control; recording equipment can be included if a record of the feed rate is desired. The experience of chemical feeding and instrument specialists will be helpful in making a choice of such equipment.

Costs of Installations

Every liquid alum installation in a water works or paper mill differs and the cost will likewise vary. Some plants have made the installations with their own personnel, some have done their own lead burning. Unused concrete tanks have been lined and costs have been less in these instances. Some consumers install duplicate transfer pumps and feeders to guard against stoppages.

Minimum facilities, including storage for 6000 gallons, have been installed for as little as $3,500 although a cost of $5,000 may be closer to the average. Recent installations for 12,000 gallon capacities have figured from $8,000 to $10,000. These values may vary in different localities and are cited only as a guide to the magnitude of installation costs.

Conclusions

One of the few opportunities to lower costs for many alum users has been provided by manufacturers of liquid alum. Evaporation, grinding and bagging are eliminated in making the liquid product, and these savings have been passed on to the consumer. There remain areas where liquid alum is still not available because of high transportation charges. In assessing the value of liquid alum for any particular location consideration must be given to the lower base cost of the chemical, freight rates, labor, safety and the cost of the equipment needed to store and feed the product. Where liquid alum use can be justified, a happy consumer usually results.

CORROSION CONTROL*

WHEN METALLIC structures, pipe or other water and sewage works equipment go into solution, the action is known as corrosion. Corrosive action in the presence of moisture, depends on pH, temperature, oxygen, characteristic of the metal, etc.

Effects of Corrosion

Corrosion in water systems may result in tuberculation (with accompanying loss in carrying capacity) and in disintegration of pipe, leaks in lines, clogging, deterioration of meter parts and leaks in domestic water heaters. Corrosion may also cause water to become turbid, colored, or to have an undesirable taste. Lead, or zinc dissolved may cause water to be toxic and copper and iron in water supplies will stain household fixtures.

In sewage works, unfavorable corrosion effects are noted in mechanical equipment as well as in the deterioration of metal structures of all kinds.

Fundamentals of Corrosion

No metal is stable in the presence of moisture and oxygen. All metals tend to be converted to oxides, hydroxides or salts of the metal and therefore to be destroyed. Corrosion is an electro-chemical process. Moore, et al, explain the mechanism as taking place in four steps: 1. Anodic Reaction, 2. Cathodic Reaction, 3. Depolarization, and 4. Reactions of the Metal Ions.—1. A metal ion goes into solution with an alectron going to the main mass of metal; 2. The metal mass gives up electrons to react with hydrogen ions in the water to form hydrogen gas; 3. hydrogen is prevented from accumulating on the metal surface by reacting with oxygen dissolved in the water; 4. The metal ions released to the water react with ions or oxygen in the water to form soluble or insoluble products, oxides, hydroxides, carbonates, etc.

If one of these steps can be prevented or controlled then corrosion can be prevented or controlled.

CORROSION CONTROL

Principal methods by which corrosion is reduced, if not prevented, are: 1. Proper selection of material; 2. Use of protective coatings; 3. Treatment of the water.

Materials

The selection of material (metallic or non-metallic) will give consideration to characteristics of the material and its resistance to the dissolving effect of water. Non-metallic materials include wood, concrete, asbestos-cement, tile and plastics.

Wood is infrequently used. Reinforced concrete is used for tanks, other structures and for sewers; prestressed concrete for water transmission mains and elevated storage tanks. Asbestos-cement is used as siding for buildings, for shear gates in sewage conduits, and for water and sewer pipe. Neither concrete nor asbestos-cement will withstand acid waters.

Tile is used for sewers, and filter bottoms in both water and sewage plants. Plastics are corrosion resistant but have a temperature limitation.

Metals commonly and widely used are cast iron for water mains; steel for structural members of buildings and for mechanisms and mechanical equipment of all kinds.

Copper pipe is used for house piping but it should be tin lined if the water is soft and contains carbon dioxide in appreciable amount. Red brass (85 percent copper) is resistant to corrosion, but if the copper content is less than 60 percent, zinc will be dissolved out in soft waters. Lead pipe can be used in hard waters, but not in soft. Aluminum is used mostly for decorative purposes, stairs, hand rails, gratings, etc.

Special corrosion resistant alloys are used for specific purposes, particularly in the handling of chemical solutions, or in sewage plants where silicon bronze is used for valves, sluice gates, etc. Rubber and hard rubber, glass or plastic are used for handling moist chlorine or chlorine in solution and other chemicals. Dry liquid chlorine is handled in black iron, steel or copper. Ceramics are used for tanks for corrosive chemical solutions.

Protective Coating

Construction of pipes and equipment of completely non-corrosive materials is generally too expensive, or the material does not have desired strength, etc. Instead materials subject to corrosion are coated with another material that is non-corrosive or at least corrosion resistant.

Protective coatings may be non-metallic or metallic. Non-metallic coatings include paints; asphalts or bitumastic, rubber, plastic, glass, and cement linings. Asphaltic and cement linings are used in water mains; rubber, plastic and glass in small pipes or tanks handling corrosive chemical solutions. Specially developed paints are applied to mechanisms and structures for water and sewage works. The old advertizing slogan, "Save the surface and you save all" is applicable in water and sewage works.

Metallic coatings are used and are useful in certain applications. Best known perhaps are zinc and lead. Galvanized iron is resistant to atmospheric corrosion but it is seldom used for contact with liquid. Copper, nickel, chromium, etc. are effective coatings for some uses, with the coating being applied by electroplating. Aluminum coatings are also used. Creation of a corrosion resistent surface of the metal itself by oxide or phosphate layer is done by Parkerizing, bonderizing or anodizing. Natural protection is afforded by the deposition of protective layers as calcium carbonate or silicates, or oxides on aluminum, etc.

Treatment

According to Moore, et al., corrosion may be prevented or reduced by treatment of the water, including pH adjustment, deposition of mineral film such as calcium carbonate, or phosphates, addition of organic corrosion inhibitors, adding agents to make the metal passive, and removal of dissolved oxygen and carbon dioxide.

Since corrosion is an electro-chemical process it can proceed under the influence of galvanic action where unlike metals are close together; stray electric currents will also cause corrosion. Best preventive for these types of corosion, is cathodic protection whereby a definite current is impressed on the metal to prevent the metal tendency to dissolve. Cathodic protection systems have been quite effective in preventing corrosion in elevated steel storage tanks, cast iron and steel pipe lines, and in sewage plant equipment.

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* Based on material in "Fundamentals of Corrosion and Its Mitigation" by Moore, Sears, and Rubin; Wat. & Sew. Wks. 100 R-102 (1953)

Effective Corrosion Control

by J. M. MEEKER

Design Engineer, Electro Rust-Proofing Corp., Belleville, N. J.

CORROSION of submerged or buried metals is an electrochemical process resulting from electric currents passing between the metal surface and the surrounding medium. Attack occurs at the points where these currents leave the structure. Conversely, no attack occurs where the currents enter the structure. The corroding areas are anodic, the non-corroding or protected areas cathodic. The so-called corrosion currents can be galvanic in nature or can be stray currents from an external source.

Mechanism of Corrosion

Galvanic currents can be compared to the action of a battery, which derives its voltage from two materials of different solution potentials in contact with an electrolyte. The potential difference in a corrosion cell can result from dissimilar metals in contact, breaks in a paint film or mill scale, stresses in the metal, differential aeration, the presence of a layer of mud or sand, or other variable factors. The battery thus set up is effectively short-circuited by the structure itself, and corrosion currents are allowed to flow.

A structure under the influence of an external potential field may suffer accelerated corrosion due to stray currents. The metal structure, which usually provides the path of least resistance, will pick up current and discharge it at another point to the surrounding medium. The point of current loss is attacked, of course, in the same manner as if the current were galvanic in nature.

This type of corrosion is commonly found where the electrolyte surrounds the structure (for example, pipelines, lead cables, harbor facilities) rather than where the structure surrounds or stores the electrolyte. Stray current sources include direct current railway systems, natural earth currents, welding machines, and cathodic protection rectifiers, on other buried structures. Both galvanic and stray currents carry metal ions into solution in an amount electrochemically equivalent to the magnitude of the current.

Methods of Control

The principal measures for controlling corrosion of this nature include paints and coatings, treatment of the corroding medium, corrosion-resistant materials, and the application of cathodic protection. Each has its advantages for some situations. Obviously, each has its limitations; for example, coatings cannot be 100 per cent perfect, treatment of the electrolyte is not always possible, use of materials subject to attack may be unavoidable, and physical factors may rule out cathodic protection.

Often, a combination of two or more methods applied to a given problem in the proper relationship to each other will produce the most effective and economical control system. For instance, a well-coated and wrapped buried pipeline will require only a small fraction of the protective current needed by a bare line. The capacity of the cathodic protection system designed to protect only that portion of the pipe left exposed by flaws in the coating will be correspondingly reduced, as will the installation, maintenance and operating costs.

Principles of Protection

The basic principle of cathodic protection, simply stated, is the transfer of the anodic process by which corrosion occurs to an auxiliary electrode placed in the electrolyte. The structure is made the cathode by reason of a direct current caused to flow to it through the surrounding medium. When the applied protective current superimposed upon the corrosion currents leaving the anodic areas of the structure results in a net current flow of zero, control of the corrosion is complete.

Protective current is supplied from galvanic anodes coupled directly to the structure, or is impressed through an anode system by an external direct-current power supply. The choice of methods is dictated by physical and environmental conditions, by economics, or both.

Galvanic anodes provide a driving voltage according to their position in the electrochemical series with respect to the metal to be protected. The two most commonly used materials, magnesium and zinc, exhibit a potential difference of 0.7 volt and 0.25 volt, respectively, to protected steel. The anode consumption rate is determined by the current flow and by the anode efficiency, which may be as low as 50 per cent due to impurities and self-corrosion.

Impressed current systems utilize a rectifier, a battery, or a direct-current generator to supply current to the anodes connected to the positive terminal. The negative terminal is grounded to the protected structure. Rectifiers are the most widely used power source due to their simplicity, durability, convenience, and ease of adjustment. Other sources are used where alternating-current supply is not readily available.

The anodes may be of the sacrificial or permanent type. Sacrificial anodes include aluminum and iron; platinum, graphite, and high-silicon cast iron are essentially non-sacrificial. The former are designed for a specific useful life and must be replaced at regular intervals. The permanent types represent a higher initial investment and are more subect to breakage and damage. Nevertheless, where conditions permit, their use may represent a substantial saving in maintenance costs.

The principles of cathodic protection have long been known. However, its major development has been within the last 20 years and it is steadily finding a wider acceptance and use. The facilities to which it is successfully applied include pipelines, water tanks, water and sewage treatment equipment, wells, ships, hulls and ballast tanks, condensers, traveling screens, steel piling, and others.

RECTIFIER unit mounted on center structure of water plant clarifier supplies protective current that flows from anodes to submerged metal surfaces of clarifier.

Limitations in Application

It is necessary to recognize the existence of limitations to the application of this method of corrosion control. These are generally imposed by the characteristics of the environment, the structure, or both. Since the fundamental theory of cathodic protection involves passage of an electrical current through a conducting medium, the soil or water must be such as to permit flow of the protective current in the required amount.

Although variations in conductivity within a reasonable range can be overcome in the design of the system, there are limits beyond which cathodic protection is neither practical nor economical. For example, it has not been successfully applied to tanks storing steam condensate, which is essentially distilled water. Also, application is considerably more difficult in some parts of the country where the water supplies are very low in dissolved solids. Fortunately, most waters and soils of a corrosive nature lend themselves favorably to the application of cathodic protection from a conductivity standpoint.

From a structural standpoint, symmetry and simplicity favor cathodic protection; complexity, shielded areas and inaccessibility work against its successful use, sometimes to the point of ruling it out entirely (for economic reasons) in favor of other control measures.

The two limiting conditions mentioned are not independent of each other; what would be a difficult design problem in a fresh water medium might be greatly simplified in sea water due to its superior conductance and the better current distribution to be expected.

Early Installations by Rule of Thumb

In the water works field by far the widest application of cathodic protection has been to water storage tanks. In the past 20 years perhaps 15,000 tanks in the United States have been placed under protection, the majority being used for some phase of public water supply.

Many of the early installations were made in a more or less standard manner without regard for the many variables which should be considered in the system design. This was due for the most part to the lack of knowledge at the time and the early stage of development of the process. The result was satisfactory operation in those cases where the conditions of the job happened to match up with the equipment installed, and only partial protection in other cases. It should be realized that in the latter cases any protective current properly applied, although inadequate in amount or distribution for complete protection, had a beneficial effect in reducing corrosion.

There have been a few devices inspired by or sold under the name of cathodic protection, and using some form of electricity, which claimed to prevent corrosion or other water troubles but which in fact had no scientific basis of operation and did not accomplish the desired result. One of these so-called cathodic protection systems involved passage of direct current through an element mounted on the outside of the tank with no other result than the consumption of power. Fortunately, it is becoming increasingly difficult to market a product whose basic principles cannot be demonstrated.

Anode Materials

Most of the early water tank cathodic protection systems used mild carbon steel rods as anode material. Although this was relatively cheap, it had the disadvantages of excessive weight, causing installation and servicing difficulties. In some cases objections were raised to the anode deterioration product.

Several grades of stainless steel have been used in an effort to provide longer life. However, performance was somewhat erratic, varying from a low consumption rate up to essentially the same rate as carbon steel.

Aluminum is the most commonly used anode material in water tanks and has several outstanding advantages. It is light in weight, easy to install, and available in a wide range of rod sizes. Its good machineability facilitates making up long anodes from standard lengths using threaded couplings or other means. Its rate of consumption under applied current is predictable, allowing the anodes to be designed for the desired life and arrangements to be made for regular servicing. The anode degradation product is aluminum hydroxide, which usually is not objectionable.

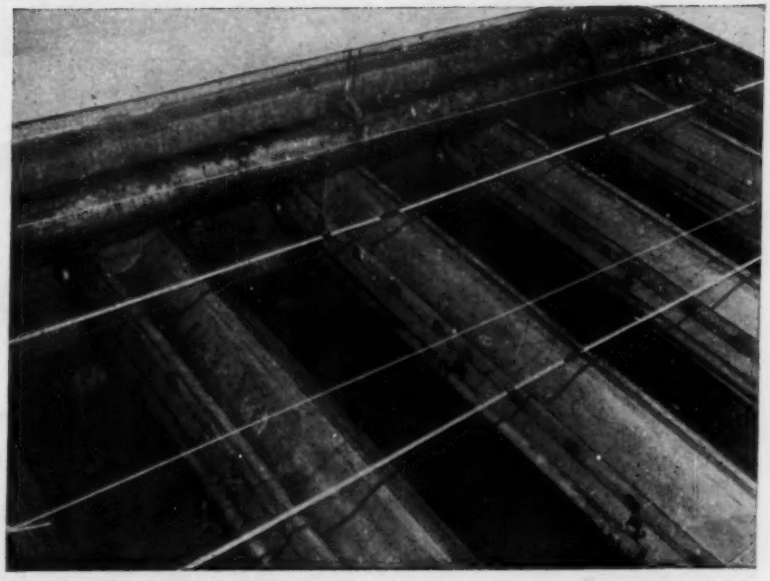
Permanent Anodes

Due to rising costs of anode materials and installation labor, there has been considerable effort toward the development of non-sacrificial anodes.

Platinum wire anodes have been used rather extensively in water tank work. Their use has become somewhat limited, however, due to several inherent disadvantages. The high cost of this material—almost $100 an ounce—requires that the anode take the form of a very fine wire. The length of anodes usually needed for tanks necessitates tying the platinum into an insulated copper feeder wire at regular intervals to prevent excessive voltage drop and current attenuation along its length. This procedure introduces the problem of attack at the joints by oxygen gas liberated by the anodic reaction. Should one or

more of these joints, which are very difficult to protect from oxidation, fail in service, the copper feeder wire will deteriorate rapidly and the anode will be lost.

Graphite and 14.5 percent silicon cast iron have been rapidly developed as anode materials and are superior in many ways. New shapes and sizes allow them to be made up in almost any form required and they show very low deterioration rates under most conditions. A distinct advantage they possess over sacrificial anodes is their stable operating voltage in a given environment, as opposed to the need for constant rectifier adjustment to compensate for the increasing resistance with time of a sacrificial anode. Limitations include somewhat higher weight and a tendency toward brittleness, requiring care in handling. Also, where icing conditions occur, fall removal is required to preserve the anodes for the next corrosion season.



ALUMINUM anode installation for protection of filter wash piping.

Anode Mounting

The most generally satisfactory method of suspending water tank anodes is from the roof plates, with a covered access opening provided at each anode location. The d-c wiring is run in conduit from the rectifier at the base of the tank to the top of the tank, and then under the roof to each anode. Most installations can be made and serviced without the necessity of anyone entering the tank.

Other water works facilities that lend themselves favorably to cathodic protection include flocculators, clarifiers, filter piping, and sludge blanket type treating equipment. For the most part these structures are considerably more complex than tanks because of the presence of baffles, rakearms, agitators and piping. Special consideration must be given to the anode design to distribute the protective effect to the various zones which are shielded from each other. In some cases as many as four separate circuits using one or more rectifier units are required.

Additional problems are introduced by rotating equipment. For example, protection of the rakearms of a clarifier requires that the anodes be mounted directly on the arms. The current must be transferred from the rectifier to the anodes through a moving contact. This is usually accomplished by mounting a ring of heavy bare trolley wire on a rotating part of the structure and a spring-loaded shoe or brush at a stationary location.

In the case of flocculators where the entire shaft and paddle assembly rotates, the anodes are mounted on the basin wall, floor, or baffles, and the current is returned to the rectifier through a moving contact on the shaft in the dry well, or even under water if necessary.

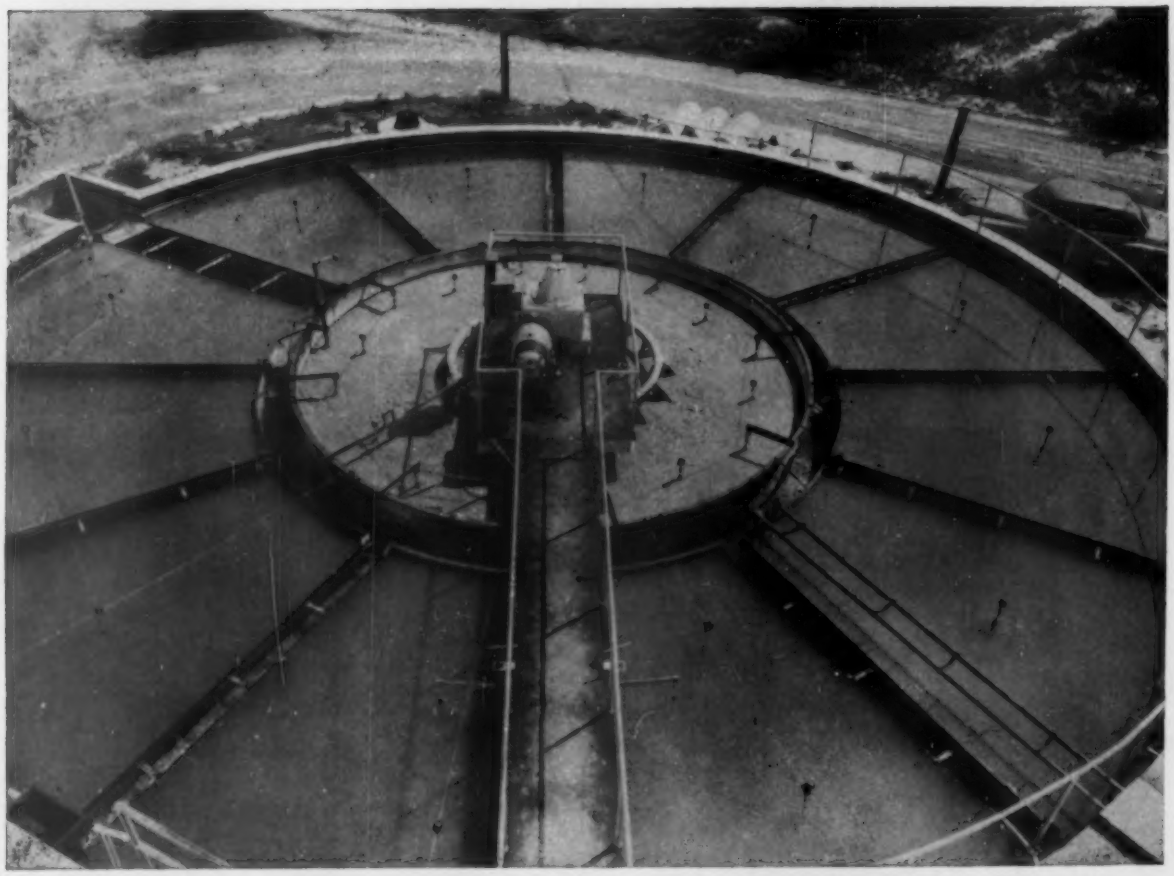
Non-sacrificial anodes are particularly adaptable to this type of equipment for several reasons. The flexibility of the segmented type, where short lengths are assembled in strings by means of special wire and connections, improves the current distribution over extended or complex areas. The spacing between anode segments can be adjusted to suit the requirements, and the anode string can follow the form of the structure.

Taking this type of equipment out of service is often inconvenient or impossible at certain times of the year. Therefore, elimination of periodic anode replacement is most desirable. In recognition of this, non-sacrificial anodes have been used for several years under the conical portion of Accelators and Precipitators. Severe icing conditions are not usually encountered in treating equipment and the anode locations can be chosen to minimize the possibility of damage.

Evaluation of Performance

Of primary interest to owners and operators is the question of how to evaluate the performance of a cathodic protection system. The most common method is visual observation, which is often convenient but sometimes unreliable. Where protection has been applied to an old previously corroded surface, appearance alone will not always disclose whether the pits are active or inactive. This can be determined by testing the pH of the contents of the pit; active pits have a low pH, whereas a value of 9 or higher indicates corrosion has been stopped. Measurements should be made immediately after draining the water. Visual inspection is more satisfactory in a scale-forming water, since the salts plated on the tank walls by the action of the protective current are evidence of adequate protection.

Test coupons or panels have also been used quite extensively. It is usual practice to ground one to the structure so that it is included in the protective circuit, and to insulate one to serve as a control. Accurate comparisons of appearance and weight loss can then be made. There are several disadvantages to this method which limit its usefulness. These include (a) the difficulty of producing the same surface conditions on both the panel and the protected structure, (b) the uncertainty that the panel will receive the same current density as all parts of the structure, and (c) the absence of the same stresses in the



WATER TREATMENT unit, showing anode arrangement for supplying and distributing protective current to all submerged metal surfaces.

panel as are present in the structure.

From an engineering standpoint, measurement of the potential of the structure to the surrounding medium is considered the most revealing method of evaluation. It has been established that when this potential is 0.85 volts or more negative, measured with reference to a copper-copper sulfate half cell placed on the protected surface, corrosion has been reduced to zero. Another criterion sometimes used is the increasing of the negative potential of the unprotected surface by the arbitrary amount such as 0.2 or 0.3 volt.

A series of these measurements, known as a potential profile, is made over representative areas of the structure using a high-resistance voltmeter or potentiometer, with the reference electrode on the positive terminal and the tank connected to the negative. Accurate equipment and proper methods must be used to obtain meaningful results, and care should be taken to cover the critical areas of the structure. Since the response of a structure to protective current is subject to change with time, periodic rechecks are sometimes advisable.

Maintenance Required

No cathodic protection system will perform effectively unless it is maintained in continuous operation and kept in proper adjustment. Most apparent failures are attributable to a tendency to overlook this point. Perhaps this is because cathodic protection is a silent process and, in contrast to the squeaking wheel that gets the grease, causes no immediate distress upon ceasing to operate.

Generally two separate maintenance functions are required. The first is regular checking and adjustment of the current output; the second, anode replacement and minor repairs. The first, of course, must be the responsibility of the owner, while the second may be done either by the owner's personnel or by contract with an outside firm offering these services. The use of non-sacrificial anodes will reduce the frequency of adjustments and in non-icing areas will largely eliminate the need for regular servicing.

There are available several methods for automatic regulation or indication of malfunction, but they have not been sufficiently developed for general use with water tank systems. Conscientious maintenance will always be the best insurance.

Summary

In summary, it may be said that in many instances cathodic protection is the one method by which the corrosion rate can be essentially reduced to zero. The requirements for accomplishing this are provision of sufficient protective current for the particular application, provision of means to distribute the current to the surface where it is needed, and continuous and proper operation of the resulting system.

LABORATORY CONTROL

EVERY WATER and sewage plant should have some laboratory facilities. The size of the laboratory and the equipment it contains should be determined according to the size of the plant and the extent of treatment. Both of these factors will affect the frequency of sampling and testing and the number and complexity of tests to be made.

Water Treatment

In most states, it is the general practice to have water samples analyzed by the state health laboratory at least once a month and for the water plant to submit a monthly report of results obtained by routine testing at the plant. Many state health departments stipulate the frequency and kind of tests to be made on a routine basis.

Chlorination

Where chlorination is the only treatment practiced, testing equipment is required to determine the amount and kind of chlorine residuals. Handy colorimetric test kits are available. This same equipment is useful in larger plants, as well.

Coagulation, Sedimentation, Filtration

Equipment for determining proper coagulation dosage is essential to good control of the process. The coagulation "jar test," made using a multiple laboratory stirrer, is the best control test. Waters requiring coagulation usually are tested for pH alkalinity, turbidity, color and taste and odor. Alkalinity requires a minimum of laboratory apparatus and pH can be determined colorimetrically with dyes. For pH, however, it is preferable to use an electric pH meter and larger laboratories should be so equipped. Turbidity tests require a turbidimeter (either candle or electric). Color tests can be made in a colorimeter, one type of which utilizes colored glass discs and the other which uses Nessler tubes containing standard color solutions.

Bacteriological Control

Where the water supply is taken from a surface supply, particularly in a flashy stream, or one subject to human pollution, it is desirable to make bacteriological tests on both raw and finished water. The most common tests are the bacteria plate count, and the presumptive or confirmed test for coliform organisms. Both require a refrigerator for keeping prepared media and a constant temperature 37°C incubator. Some special laboratory glassware and a bacteria colony counting device are also required.

Taste and Odor Control

Most of the taste and odor problems in water supplies come from algæ. Treatment of algæ in reservoirs, particularly with copper sulfate, must be controlled according to the type of algæ present. In order to identify the algæ organisms, a laboratory should be equipped with a microscope and pertinent equipment.

Softening

In addition to pH and alkalinity tests in softening, hardness determinations should be made. In large softening plants more complete chemical analyses are made to determine calcium, magnesium, sulfates, chlorides, etc. Also, the laboratory is usually equipped to analyze the chemicals purchased. A fairly well equipped laboratory is required.

Sewage Treatment

Many state health departments require sewage plants to submit monthly records of routine tests and in some cases stipulate the tests to be made according to the size and type of treatment plant.

Primary Treatment and Chlorination

In the smallest plants, where only primary treatment is used, such as Imhoff Tank plants, settleable solids by volume are required, using the Imhoff cone test. In some small plants, the methylene blue stability test is also made. When chlorination is also used, residual chlorine tests should be made but the type of residual is not important.

In larger plants utilizing primary treatment only, the tests made will include suspended solids, B.O.D. and possibly pH and alkalinity. If gas from separate digestion is collected and used, gas analyses may be made. Where chlorination is important to the control bacterial pollution of the receiving waters, bacteriological tests must also be made as well as chlorine demand tests and chlorine residual tests. Special tests on settleable solids by weight may also be made.

All of these tests require a certain amount of laboratory apparatus and glassware for specific purposes. In addition, B.O.D. tests require a constant temperature 20°C incubator. Solids determinations require an analytical balance, steam or water bath, drying oven and muffle. Gas analyses require special analytical apparatus, but pH, alkalinity and bacteria require the same equipment as used in the medium and large sized water works laboratories. Chlorination control uses the same equipment as used in water works.

Secondary Treatment

If trickling filters are used, B.O.D. tests are required. The activated sludge process likewise requires the B.O.D. test and control tests using dissolved oxygen determinations, sludge volume and density determinations. None of these require any additional types of equipment to that already outlined.

Sludge Dewatering

When sludge is digested, some control tests are made on the raw and digested sludge. Usually these are total solid matter, volatile matter, pH and alkalinity. The same equipment is used as for testing raw sewage. If the sludge is dewatered on vacuum filters, control tests are necessary to determine the proper dosage of chemicals. For this control, pH, alkalinity and other special tests may be used, but no special apparatus is required except a pH meter.

If the dewatered sludge is dried or incinerated, moisture and volatile matter determinations may be made on both the cake and the dried sludge.

Sampling and Control

The location of sampling points and the number of samples to be collected at each point during a day, will depend on the size of the plant, the degree of treatment required, the receiving body of water, etc. In small plants, grab samples may be permitted, in medium sized plants samples representing several hours out of the day, should be collected and composited. In large plants samples should be collected every hour and composited for the 24 hour period. Where composite samples are used a refrigerator is necessary in the laboratory.

Laboratory equipment in any sized plant should be housed in a separate room (or rooms) well equipped with benches, sinks, drawers, cabinets and other normal laboratory fixtures. For many tests there are now special instruments for making the necessary determinations; such equipment is recommended for the larger plants.

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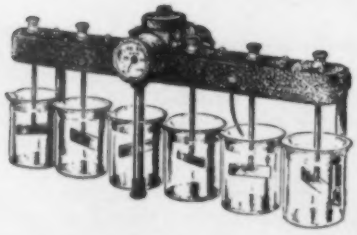

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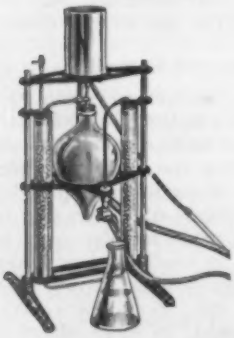

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Membrane Filter Procedure

Advantages and Limitations

by H. F. CLARK, P. W. KABLER and E. E. GELDREICH

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THE MEMBRANE FILTER procedure offers a rapid and reproducible method for the estimation of coliforms in samples of most treated and untreated waters.

Advantages of this procedure are availability of data within less than 24 hours, elimination of some of the errors of the multiple-tube method, and reductions of space, material and equipment with approximately one-half the labor of technical work and preparation.

The filtration procedure also has its limitations, which require that a certain degree of judgment must be used in its application to the examination of samples. Samples where the filtration procedure cannot be used are generally easy to recognize. Typical examples are the presence of gelatinous flocs, presence of algae in quantity, or samples with high non-coliform density and very few or no coliforms present. These limitations can be observed during the test, making it easy to eliminate unreliable data in the filter method. Errors that occur in the multiple-tube procedure are difficult to recognize and time consuming to demonstrate.

During World War II, German military and civilian authorities used a membrane filter for water examinations following the destruction of laboratory facilities by strategic bombing. With the release of the membrane filter for civilian use after the war, many manufacturing improvements were made. The filters are currently being manufactured in the United States, Germany, England, and perhaps in other countries.

What the Filter Is

The membrane filter is a thin wafer composed of esters of cellulose with an effective pore diameter of 0.5 micron and consisting of approximately 80 percent voids. The conical pore has its axis perpendicular to the flat surface and its narrow diameter at the top surface. Membranes may be obtained in a variety of sizes to fit any filtering apparatus, but those used in this country are usually 47 mm or, rarely, 50 mm in diameter.

For convenience in counting colonies, the membrane is usually grid printed, with the size and number of squares being a matter of individual preference or manufacturing policy. In addition to the membranes and absorbent pads, a filtering apparatus and liquid media designed for membrane filter techniques are the only special equipment needed which will not be found in the average bacteriological laboratory concerned with the examination of water samples.

Methods for filter tests are easily mastered and can be used routinely in the laboratory, but recommended procedures must be carefully followed for best results. The current status of the tests in the individual location should be investigated before consideration of the various filter techniques for the examination of water samples other than for experimental data or research investigations.

Tentative Acceptance

The tenth edition of "Standard Methods"[1] describes the test as a tentative procedure, but fails to recommend its use on official samples where equivalent results are demonstrated by filtration methods and multiple-tube methods. It also states:

> The study indicates that there is no readily apparent relationship between results secured by the membrane filter technique and the standard dilution tube procedure upon which the Most Probable Number index is computed.

This sentence, with the omission of approval with equivalent data and the absence of any values to be used as a guide in the interpretation of data by the filtration procedures would, under strict "Standard Methods" regulations, limit its use to research investigations and supplemental examinations.

Acceptance By Others

The "Interstate Quarantine Drinking Water Standards" recognize the membrane filter test as described in "Standard Methods" as an official procedure in the examination of potable waters for interstate carrier water points and other waters under the quality control regulations of the Public Health Service or other agencies of the U. S. Government. This authorization is found in the "Intention to Amend" published in the *Federal Register*, October 23, 1956, pages 8110-1, and amended in *Federal Register*, March 1, 1957, page 1271.

The standards of interpretation for the membrane filter test are defined with the permissible limits for the occasional occurrence of coliforms in a potable water sample. This authorization of the membrane filter procedure as an official alternate test does not apply to water under control of intrastate regulations, but it does signify acceptance of results wherever it may be used as an official test.

With the foregoing differences in the "Standard Methods" and the "Interstate Quarantine Drinking Water Standards," it would appear that the Board of Health having authority in any political subdivision could approve the membrane filter procedure for the bacterial examination of water where it considers it applicable, including interstate water points, without further approval, except in states where "Standard Methods" have been adopted by legislative action.

The "Interstate Quarantine Drinking Water Standards" provide for the interpretation of results of the test applied to potable waters. Briefly the provisions are as follows:

1. Arithmetic mean density of all standard samples examined per month by membrane filter procedure shall not exceed one coliform per one 100 milliliters.

2. An occasional sample may have:
(a) 3 coliforms on a 50-ml sample, or
(b) 4 coliforms on a 100-ml sample, or
(c) 7 coliforms on a 200-ml sample, or
(d) 13 coliforms on a 500-ml sample, or
(e) 22 coliforms on a 1,000-ml sample,

Providing it does not occur in
(1) Consecutive samples, or
(2) More than five (5) percent of samples when 20 or more samples per month are examined, or

(3) More than one sample when less than 20 samples are examined per month.

3. Provided further, that when one sample exceeds the above permissible limits, daily samples will be collected and examined until two consecutive satisfactory samples have been recorded.

The Technical Committee on Methods for the Bacteriological Examination of Boundary Waters (Jan. 20, 1957) believed that, after consideration of available information, the results of examination by membrane filter procedures and those obtained by the confirmed MPN test of "Standard Methods" were of equal sanitary significance in the interpretation of water quality. The membrane filter procedure was approved with the recognition that there would be occasional instances where an indeterminate MF result would occur due to algae, excessive turbidity, or colloidal precipitates, which would require a multiple-tube (MPN) test.

A few cities are now using the membrane filter test exclusively for potable water samples from both the plant and the distribution system. A larger group of cities are using both MF procedures and MPN tests while deciding which procedure to adopt.

Laboratory Errors

The technical procedures and equipment for the membrane filter test are fully described in "Standard Methods"[1] and in various publications in technical journals. Here are considered only certain parts of this procedure in which have been encountered the most frequent laboratory errors or mistakes in technical judgment.

Some laboratories have reported errors in technique as failures or as limitations of the membrane filter test. Common errors which may result in poor coliform determinations are:

1. Excessive number of colonies on membrane.

2. Errors in basic fuchsin-sodium sulfite ratio.

3. Elimination of enrichment period.

4. Low humidity during incubation.

5. Flooding membrane with medium.

6. Contamination of absorbent pads.

7. Air bubbles between membrane and absorbent pad.

Ideal membranes should have less than 60 coliform (sheen producing) colonies and not more than 250 or 300 total colony count. However, reasonably good estimated coliform counts can be made on membranes with 100 coliform colonies when the noncoliform colony density is low. Exceeding these limits results in missed coliform colonies due to suppression of sheen or a spreading growth over membrane with few distinct colonies. In estimating the size of the sample for filtration, the use of past coliform data is helpful. Such calculation should aim at a coliform colony density of 20 colonies on the membrane.

In the absence of any coliform data, three or four different quantities of water should be filtered the first time in order to establish an appropriate quantity for examination. In the examination of potable waters, 50- or 100-ml samples are most frequently used for untreated waters. For treated waters (including those treated by chlorination only) in the order of preference, best results are secured with 200-, 300-, or 100-ml samples. Samples of 100-ml size are generally used for examination of water from mains before resumption of service after repairs or installation of new lines.

Another source of poor results by the membrane filter procedure is an error in the ratio of basic fuchsin to sodium sulfite, used as an indicator system in the medium. An excess of basic fuchsin results in a toxic medium, with suppression of many coliform colonies. An excess of sodium sulfite inhibits the typical metallic sheen production by the bacteria of the coliform group.

Each lot of basic fuchsin must be biologically standardized for the fuchsin-sulfite ratio which will yield maximum coliform recovery with optimum coliform differentiation. If the biological standardization of the indicator system cannot be made in the plant laboratory, a few comparative tests should be made to show whether the fuchsin-sulfite ratio prepared locally gives results equivalent to those obtained with a sample of indicator which has been biologically tested. Samples of moderately polluted water should be used for comparative tests. Sewage or pure cultures should never be used in this standardization.

An enrichment period of approximately two hours on a nontoxic and nonselective medium is recommended. Some samples, such as fresh sewage with active coliform populations, show little decrease when the enrichment step is reduced or eliminated. It is essential, however, in waters where the coliforms have been exposed to any unfavorable environmental conditions. The enrichment period initiates growth of weakened or resting coliform cells. It may be considered comparable to the lactose-broth step in the confirmed test by the MPN procedure, in that it initiates growth in the absence of restrictive substances.

Reduced humidity frequently will permit the surface of the membrane to lose moisture more rapidly than it is replenished by the diffusion of medium from the absorbent pad. This may result in suppression or reduction of growth. A number of simple and inexpensive corrective procedures have been described in the literature to use in any type of incubator.

The next two sources of error can easily be eliminated by removing the excess medium from the absorbent pad before rolling the membrane on it, and by using sterile absorbent pads. Air bubbles between the membrane and absorbent pad can easily be recognized on SEC Endo-type medium by a colorless spot in the membrane. A membrane with no air bubbles on this medium is uniformly pink. The remedy for bubbles is to lift the membrane with sterile forceps and roll it again on the absorbent pad.

Observation of precautions to avoid the foregoing seven possible errors will eliminate the majority or disappointments and dissatisfaction with the membrane filter test. Excessive crowding of the membrane or poor media, with special emphasis on the fuchsin-sulfite ratio, are far the chief causes of poor results and unsatisfactory tests.

Other Limitations

There will be samples of water and sewage, with their great variety of pollutants found in some locations, for which the membrane filter procedure should not or cannot be used. These limitations can usually be recognized from the history or an inspection of the sample, during the filtration pro-

cedure, or an examination of the membrane after incubation. Most of these samples belong in one of the following groups:

1. Contain large quantities of colloidal precipitate or suspended solids in reference to quantity filtered.

2. Have an excessively high noncoliform bacterial population that can grow on an Endo-type broth with a negligible coliform density.

3. Contain at least 1 mg per liter of zinc or copper compounds, or both, as reported by Shipe and Fields (*Appl. Microbiol.* 2:382-384; 1954).

4. Contain (in a rare water sample) a bacterial strain fermenting lactose with rapid acid production on Endo-type broth but failing to produce gas in lactose broth fermentation tube.

The presence of suspended material in the sample may or may not be a limiting factor in the use of the membrane filter procedure. It will depend on the type of the suspended material and the thickness of the layer on the surface during incubation of the sample. Relatively thin layers of gelatinous or hydroscopic materials as suspended iron, manganese, or alum flocs, or algae, may clog the pores of the filter or they may, after incubation, result in a spreading film of growth.

On the other hand, much thicker surface layers of crystaline or silicious materials may cause little or no difficulty. The application or limitation of the procedure will not only depend on the thickness and nature of the suspended material on the surface of the membrane, but also on the density of coliforms. If the coliform pollution is sufficient to examine a sample not exceeding 2 or 3 ml in size, there is practically no danger of collecting sufficient suspended material, even algae, to cause any difficulty. However, if the quality of water is such that large quantities containing suspended material must be filtered, a multiple-tube method should be used. Pollution in streams like the Missouri, Mississippi or Ohio Rivers is sufficient to use the membrane filter procedure (over 500 coliforms per 100 ml).

An occasional water sample will contain 400 or more noncoliform bacteria capable of growing on Endo-type broth for each coliform organism present. This occurs infrequently because the Endo-type medium suppresses the growth of a large percentage of noncoliform bacteria normally present in water and sewage. This limitation has occurred twice in the experience of the authors, and both streams producing such samples were high in the western mountains. In such cases the membrane filter test cannot be used.

Some waters high in industrial wastes have been found to contain more than 1 ppm of zinc or copper compounds. Shipe and Fields have reported that the metallic ions are adsorbed on the membrane sufficiently to prevent bacterial growth. In such instances a multiple-tube test would be the procedure of choice.

Occasionally a water sample is encountered which contains a strain of bacteria able to grow on the Endo-type medium with a metallic sheen. These organisms produce large quantities of acid, but no gas in lactose broth. Because they are apparently confined to a very few locations and appear in these places only periodically, it has little effect on the application of filter techniques. They can be easily identified by transferring a number of sheen-producing colonies to lactose broth tubes with an indicator to show acid production. They are characterized by rapid acid in 24 hours at 35°C and failure to demonstrate gas production in 48 hours.

Advantages

From this discussion it appears that the membrane filter procedure is applicable in the majority of untreated waters. Certain limitations have been suggested in the application of the test, but from a practical consideration only those samples high in iron or algae and very low in coliform density will cause much difficulty. Such samples may be encountered in the examination of well waters or in some impounded waters or lakes.

Membrane filter application in the examination of filtered waters appears to have no exceptions from a technical viewpoint. Its major advantages are the examination of 200 to 400 ml of treated water, reproducibility of results, and completed examinations in less than 24 hours. In those plants where it is routine practice to examine further coliforms found in finished water, isolated coliform colonies can be picked directly from the membrane.

A delayed incubation membrane filter test has been developed to permit the filtration of a sample in a local water plant and completion of the test in a central laboratory. The procedure consists of filtering the sample, placing the membrane on benzoated Endo-type (preservative) medium in a sterile 1-ounce ointment tin, and sending it to the central laboratory. In the central laboratory the membrane is transferred to SEC Endo-type medium and incubated at 35°C for approximately 18 hours; then coliform colonies are counted as they are for the immediate membrane filter test.

Membranes reaching the central laboratory within 72 hours give coliform data equivalent in sanitary significance to data obtained from liquid samples stored at 5°C for 24 hours. Practical advantages are:

1. Membranes after filtration on preservative medium are stored or transported at ambient temperature without refrigeration.

2. Transportation cost is approximately 3 cents per sample plus 6 cents for the mailing carton which will accommodate up to seven samples.

3. Changes in coliform densities on the preservative medium are generally negligible between collection and analysis.

4. A single central laboratory can supply bacteriological services to numerous small water supplies or examine samples in collaboration with other laboratories.

The same precautions and limitations apply to the use of the delayed incubation test as for the direct membrane filter procedures. The delayed test has been extensively investigated during the past year by parallel examinations of raw and treated water by the delayed incubation procedure, immediate MF procedure, and "Standard Methods" MPN test on about 5,000 samples from 14 locations in the continential United States.

Preliminary analysis of the results indicates that the delayed incubation MF technique yields results comparable to the immediate MF test and similar in sanitary significance to the results by the MPN procedure. The delayed test is useful especially for testing waters that cannot be examined soon after collection and must be sent by public transportation to a laboratory for analysis.

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Ed. Note: Although "Standard Methods" is published by the Am. Pub. Health Assn. it is now produced, and sold jointly by the Am. Water Works Assn., the Federation of Sewage & Ind. Wastes Assns. and the Am. Public Health Assn.

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Compressed Air and Gas Institute, Cleveland, Ohio

SEWAGE treatment requires compressed air at various pressures and in varying quantities throughout most of the processes employed. From the aeration of grit chambers through the pneumatic conveying of dried sludge, compressed air demonstrates its versatility. Regardless of the size or type of treatment plant considered, compressed air is a necessary ingredient in a multitude of applications.

Municipal water supply sources normally consist of wells, reservoirs, lakes or rivers; the water from each requires pretreatment. The principal objectives of pretreatment are to provide water not only free of harmful bacteria, but also of low hardness and with good taste. Pretreatment may consist of filtration, sedimentation, demineralizing, aeration, coagulation, softening and carbonation. Compressed air may be utilized to make water available from wells through air lift pumps or starting engine-driven pumps, in pretreatment processes, and in the laying and maintenance of mains to distribute the water for residential and industrial consumption.

Aeration

Aeration is the common method used to keep sewage and sludge aerobic and agitated in effecting stabilization by the activated sludge process. Aeration mixes the primary treatment effluent with the activated sludge, keeps the sludge in suspension, and supplies the oxygen required in the biological oxidation process. This process utilizes compressed air by discharging it through submerged diffusers of porous materials installed at or near the bottom of a tank under a 10- to 15-ft depth of sewage. The diffusers, in plate or tube form, are positioned in the tank in such a manner that a rotary or rolling motion is imparted to the sewage.

The amount of air required for suitable treatment is dependent on the strength of the sewage. Reported requirements are 0.5 to 1.5 cubic feet of air per gallon of sewage. Some engineers design for 1,000 cubic feet of air per day per pound of B.O.D. removed. The air pressure required varies from 6 to 9 psig.

Aeration without the production of an activated sludge, or "plain" aeration, is used quite often in the treatment of many types of industrial wastes. Waste reduction is accomplished mainly through a greater removal of suspended solids. Although not as efficient as activated sludge, plain aeration is used in the treatment of citrus cannery, oil refinery, dairy and pharmaceutical wastes. The air requirements again are dependent on the strength and type of waste being treated, but are comparable to those for activated sludge.

Aeration in water treatment is normally employed to oxidize dissolved iron or manganese and to reduce carbon dioxide and other gases. Aeration of water is accomplished by passing it through the air (as in a cascade), or by passing air in bubbles through the water. In most plants the latter method, of course, involves oil-free compressed air supplied by means of rotary blowers of the positive displacement type, although centrifugal blowers are used in large plants. Diffuser tubes or plates are used in the water tanks, with aeration for about 15 to 20 minutes being normal practice. Air requirements generally range from 0.05 to 0.10 cubic feet of air per gallon of water being treated.

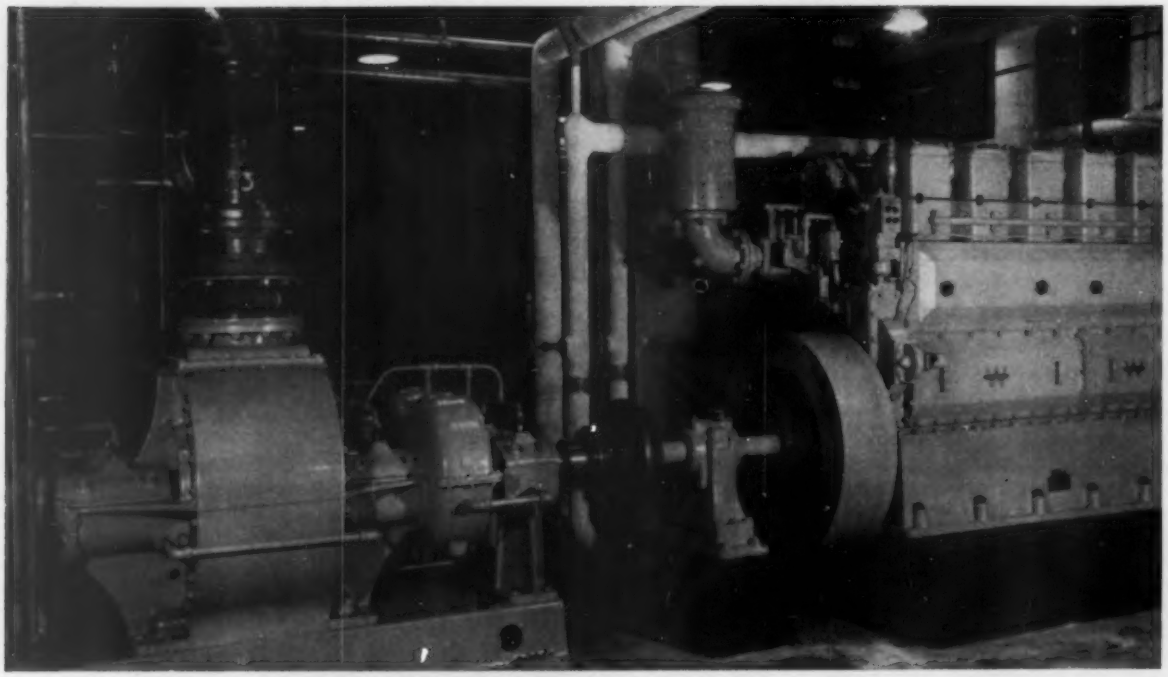
Grit Separation and Removal

Air diffusion or controlled aeration is often used to accomplish removal of grit from sewage in tanks or chambers similar to those used for activated sludge treatment. Grit removal in the early steps of treatment alleviates wear and operating troubles on equipment in subsequent treatment processes, and minimizes the accumulation of non-organic material in digestion tanks. Grit chamber diffusers are usually located higher than in the activated sludge tanks and above a sump permitting the grit to be collected and removed. The spiral motion of the sewage in the grit chamber rolls the grit towards and into the sump while organic solids are kept in suspension to pass on to the next treatment unit. Few organic solids are accumulated with the grit, due to the washing action of the sewage while the grit moves to the sump.

The recommended tank velocity is 1 to 2 feet per second. This velocity, imparted by air diffusers, moves the grit to the sump, where it drops out of the sewage, but keeps the organic solids in suspension. Air requirements vary with the size of the chamber; pressures of 5 to 8 psig usually are required. Some treatment plants utilize separate blowers for grit chamber air; others use air from the main air blowers, which also supply air to the aeration tanks. Grit removal is accomplished by screw conveyor, jet pump, clamshell bucket, or air lift.

Air Lift Pumping

The air lift is one of the oldest applications of compressed air, its principles having been discovered late in the 18th Century. It was first used to pump clear water from deep wells and began to be used for sewage treatment work about 1900. It is a device for raising liquids or waterborne solids through a vertical pipe, partially submerged in the liquid, by means of compressed air injected near the lower end of the pipe. The air introduced disperses through the liquid to create a column of mixture, filling the pipe to its full height, and weighing less than a liquid column of equal horizontal area on the outside, extending from the bottom of the pipe to the surface



LARGE rotary blower supplying air to sewage aeration tanks.

of the liquid. The unequal pressure created causes the column of mixture (liquid and air) in the pipe to rise and overflow the top. The high-lift air lift now in use on deep wells is claimed by its manufacturers to produce more water from a normal well at less cost than any other known method of pumping. The low-lift air lift is more suitable for handling waterborne solids and has found extensive use in sewage treatment plants.

Air lifts are simple in design and construction, requiring a minimum of repair. They need little space, can be accurately regulated to handle variable flows, will pass solids of large size, and can be constructed of materials resistant to acids and alkalis. They are well fitted for sewage treatment applications because of positive regulation of flow, the aeration effect of the compressed air on sewage or sludge, and the unimpairment of the settling qualities of sludge handled.

Air lifts are advantageous in water treatment plants because the power source is centralized and a group of wells at widely separated locations may be served by a single compressor and motor. If oil-free air is used the water is uncontaminated by the pumping medium, thereby possibly reducing filtration and/or purification requirements.

The air requirements for air lift installations vary with the size of installation and the submergence of the unit. One manufacturer lists air requirements of from 5 to 500 cfm.

Pneumatic Conveying

Large water and sewage treatment plants generally buy alum, soda ash, ferric sulfate and lime in bulk. These materials are usually unloaded to elevated bins by a conveyor system, either mechanical or pneumatic. Pneumatic conveyors involve the simple principle of blowing material through a tube with air pressure, or sucking material through a hose or tube by vacuum. They are clean, safe and economical. Air conveyors utilizing suction or pressure or a combination of both, are available to convey materials from car or truck to bin, and from storage bins to actual points of use such as feeders and mixers. Conveyor manufacturers will engineer the system and furnish all necessary appurtences, including feeders, filters, blowers and discharge locks.

Pneumatic conveying systems are offered to handle capacities ranging from 100 pounds to more than 100 tons per hour. A single system can handle many types of material without mixing or contamination. The system cleans itself after each transmission. Dust created in unloading and filling operations can be collected and exhausted to the atmosphere or collected for use.

Oil-free air is required for pneumatic conveyor service, the quantity being dependent on the rate of flow desired, the material being handled, the size of piping used, and the distance the material is to be moved. The

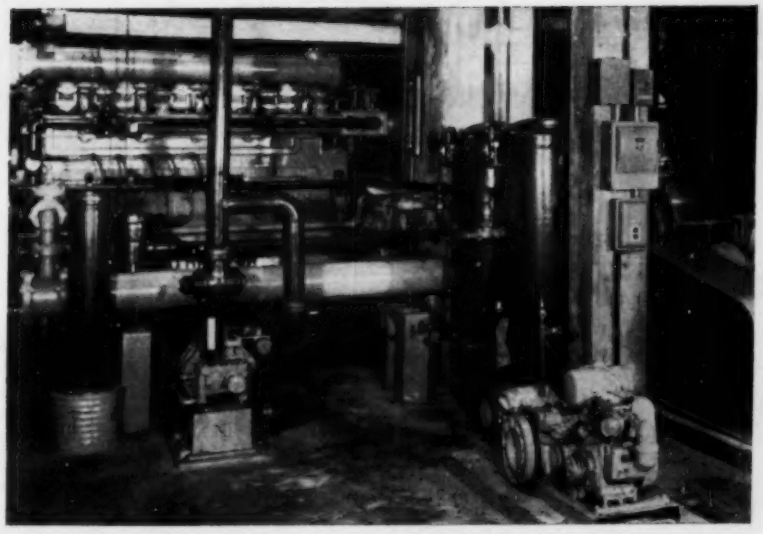
Applications of Compressed Air in Water and Sewage Treatment

- Aeration of water, sewage and sludge
- Agitation and mixing
- Air displacement pumping
- Air lift pumping
- Backwashing sand filters
- Blowing filter cake
- Cleaning of material
- Draining of water mains
- Dust control
- Engine starting (gas and diesel)
- Engine turbocharging
- Flocculation
- Flotation
- Flushing of water mains
- Forced draft for incinerators
- Grit separation and removal
- Maintaining water pressure
- Odor control
- Operation of air motors
- Operation of pneumatic hoist
- Operation of remote and automatic controls
- Oxidation
- Painting of equipment
- Pneumatic conveying
- Power for maintenance tools
- Vacuum sludge filtration

flushing with air and water continues until the water leaving the risers no longer carries any deposited material. This system is economical, eliminates many taste and odor complaints, and may increase materially the carrying capacity of older water lines.

Water-filled excavations and ditches may be pumped dry with small air lift pumps operated from portable compressors. Rocks and gravel are handled without fear of equipment breakage often experienced with centrifugal or reciprocating pumps.

Plant air or small rotary blowers are used in many sewage treatment plants to provide air for pneumatic hoist and lift operations. Swing-type diffusers are often pneumatically lifted from aeration tanks and grit chambers for cleaning and replacement of parts without emptying the tanks. Portable hoists are available with integral mounted blower that can be moved from one tank to another as required.



SMALL compressor providing starting air for a gas engine.

Miscellaneous Uses of Air

All water, sewage and industrial waste treatment plants require air for purposes not usually connected with the pumping or treatment of water and sewage. Engine starting, engine supercharging, boiler tube cleaning, soot blowing, control instrumentation, and pneumatic valves depend on compressed air for successful and efficient operation of modern plants. Compressed air enables many of these functions to be performed automatically with savings in manpower and equipment.

Bourdon tubes, diaphragm pilot valves, and bellows activated by air permit plant operators to pick up pressure and volume changes in a system from a central control room. The sensitivity and dependability of compressed air has been significant in the use of air-controlled plant equipment, such as scales, chemical mixers, chlorinators, boiler feed pumps, driers, and deodorizers.

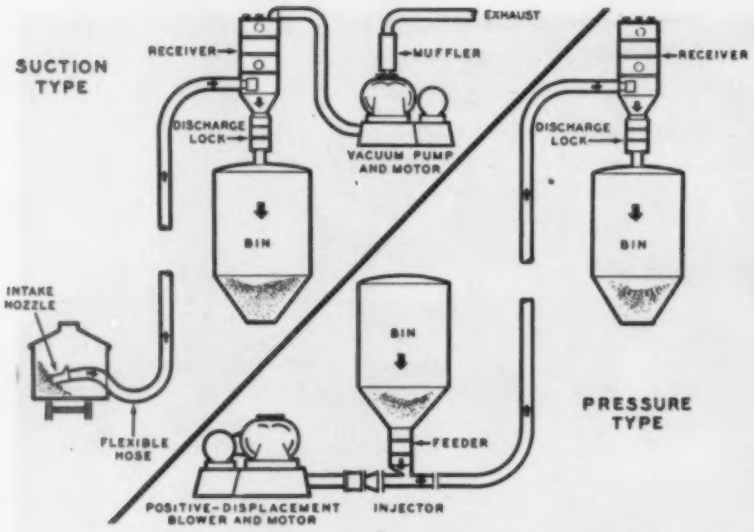
Versatility Unexcelled

Mention of a few of the many applications of compressed air in water and sewage treatment plants (see accompanying table) illustrates its versatility and importance in this field. The dependability, sensitivity, availability, convenience and relatively low cost of compressed air in this type of plant make it subject to ever-increasing use.

Careful consideration must be given, however, to the source of air supply for specific applications. Aeration, pneumatic conveying, agitation, instrumentation and control all require oil-free air with a minimum of moisture. Many of these applications require blowers and compressors to operate with a minimum of down time and maintenance. Space requirements, capacity and pressure needs, flexibility, accessory equipment required, and power consumption, are prime considerations in the specification and selection of blowers and compressors.

Blower and compressor manufacturers are anxious to assist in the selection of air supply equipment whenever possible, to insure the use of the best unit for the application at hand. But the equipment manufacturers are occasionally limited in the amount of assistance they can render by the quantity and quality of performance and process data submitted for blower and compressor selection. Consequently, the consulting engineers or municipal authorities share the responsibility for the selection of proper units. Adequate information insures the selection and use of blowers that will supply air economically, with minimum down time, and with sufficient capacity for future expansion.

PNEUMATIC hoist utilizing small rotary blower for air supply.



PNEUMATIC conveying systems for use in water or waste treatment plants.

average pressure system requires 6 to 9 psig; the average vacuum system, 10 to 20 inches Hg.

When dry chemicals are moved by conveyor belts, they are still fluffed by compressed air to prevent clogging and to facilitate handling.

Pneumatic conveyors are utilized by some of the larger municipal sewage treatment plants to convey dried sludge to loading docks or bagging operations.

Pre-Aeration

Use of the term "pre-aeration" in sewage treatment refers to the use of air ahead of the standard processes of primary or secondary treatment. Pre-aeration is accomplished by diffusing compressed air into the influent, resulting in better odor control, more efficient grease removal, higher dissolved oxygen content of raw sewage, and reduction of the organic load on subsequent treatment units. It has been used to maintain desirable effluent quality in an overloaded plant until such time as additional capacity is available through new construction.

Most authorities suggest pre-aeration detention time of 30 to 45 minutes at design flows, with a minimum air input of 0.1 cubic foot per gallon. Air requirements vary with the type of equipment used and the objectives to be accomplished.

Cleaning Sand Filters

Sand filters are commonly used where a more complete removal of suspended solids is desired than is possible by sedimentation or with trickling filters. These filters, utilizing sand or some other fine porous material, remove solids that are smaller or less readily settleable. The filter beds can be cleaned or reactivated quicker and more effectively by compressed air.

Agitation of the sand or filtering media with low-pressure air considerably reduces the cleaning time. This speed of filter reactivation is vital during the summer months when water consumption is normally at a maximum. Air at from 8 to 10 psi is normally used for this application, supplied by separate blowers or taken from the plant air system. If plant air is used, pressure regulation is accomplished by the installation of valves on the air piping to the filter beds. Various types of equipment may utilize air pressure and force the air through the filter media; or may create a vacuum above the media and draw air through it.

Sludge Filters

The conventional type of vacuum filter utilizes a drum partially submerged in a vat containing the sludge to be dewatered. The surface of the drum is covered with a filter medium, through which water is drawn from the sludge as the drum revolves through it. Solids are accumulated on the drum in a layer or cake, which may be ¼- to ⅜-inch thick. As the drum emerges from the sludge tank, the filter cake is further dewatered by drawing air through it with a vacuum pump. Stratification of sludge in the sludge tank may be prevented by agitating it by means of compressed air.

Separation of the cake from the filter medium is accomplished by the application of low-pressure air to the back of the medium or drum as it completes its revolution and is scraped into hoppers or onto conveyors.

Flotation

Industry has long utilized the process of flotation in the mining of coal and ores and in metal refining. Its use has recently been extended to wastes treatment, particularly in industrial waste treatment. Solids will separate from a liquid medium, either by settling due to gravity or by floating to the surface if they are lighter than the carrying liquid.

In wastes treatment, engineers and plant operators are faced with the problem of bringing solids to the surface of the wastes as rapidly and effectively as possible. Not only are they concerned with solids slightly lighter than water, but they also try to get those heavier than water to the surface where they can be skimmed or drained off. If these heavier solids can be combined with or attached to a material lighter than water, the new material or mixture will rise to the surface. This requirement is often met by the use of air. Diffused air is commonly blown into the waste, where the air bubbles attach themselves to the solids and carry them to the surface.

Plant and System Maintenance

Compressed air is an invaluable aid in plant and system maintenance, regardless of the type of municipal utility. Economics, safety and convenience dictate the use of compressed air as the source of power for maintenance tools and service operations. Repair shop tools, removing water from mains, earth tamping, paint spraying, ash and soot removal, rock drilling, and pavement breaking, all utilize compressed air from stationary or portable compressors.

Water mains up to 20 inches in diameter have been dewatered satisfactorily and quickly with 100-cfm compressors. This is particularly helpful in replacing old mains with new ones when water users and fire protection are involved.

Some municipalities utilize air pressure in flushing smaller water mains. Flusher-risers are installed in the mains at predetermined intervals and compressed air is put into the line through service connections. All water in the line is forced out through the riser by the air. Air at about 90- to 100-pound pressure is put through the empty main to loosen scale, rust, algae and other foreign matter. The main is then flushed with water at normal pressure to carry away the material loosened by the air. This alternate

General Plant Maintenance

by WALLACE GRANT

Chemist, West Virginia Water Service Co., Charleston, W. Va.

ALMOST EVERYONE, nowadays, has had the experience of maintaining an automobile. But, there is a considerable range of practice as to how well the automobile is maintained. One person will have an oil change and general lubrication at each 1,000 miles of driving, will keep the car clean, will buy new tires when the tread of the ones on the car become thin, and, in general, will maintain the car in tiptop condition at all times. Another person may change oil and have the car lubricated at intervals of 2,000 miles or less frequently, have it washed only when the spirit (or his wife) moves him, and still be quite successful in having the car operate efficiently. And so on, to the man who never changes oil, sets his car out in the rain and hopes that will get it clean, etc.

As in maintaining an automobile, so in maintaining a water plant there are practices which range from the excellent to the very poor. Good, sound, and accepted maintenance practices for the water plant operator, and his responsibility for them, are the subject of this article.

The first principle of water plant maintenance is plant appearance [3]. A man may keep a shabby auto if he so desires, but a water plant is different in that it is a public utility and the operator has a public trust to keep it neat, clean, and operating properly. Even the smallest and most remote plant can be kept reasonably clean and neat, except during times of major repair, addition of new facilities, or extreme emergencies.

Proper maintenance is to a large extent just good housekeeping, which means keeping the building and grounds clean and attractive. Brooms and mops, used regularly, are important tools for this work. Where it can be obtained, a heavy-duty vacuum sweeper is of great assistance in keeping the plant clean. These units, which can be purchased for less than $300, can also be used as blowers when needed [7].

Dust collectors on dry feeders are of great assistance in keeping feed rooms clean.

A proper program of painting will help the appearance of the plant; it is the least expensive method of protecting and maintaining surfaces [8]. Paint pays its way in reduced corrosion and decay, when properly applied. The improved appearance is a bonus which costs nothing.

As in the case of the man who keeps his automobile neat and clean, so a water plant which is neat, clean, and orderly will probably be better maintained generally than one which is dirty, cluttered, and unattractive.

At this time It should be pointed out, however, that some plants are poorly designed, as far as keeping them clean is concerned. Dry feeders and storage for chemicals may be in the same room with the filters, or pumps, or both. In such cases it certainly requires more work and constant care to keep a plant passably clean.

Cartoons drawn by George M. Keeney, of the Engineering Department, Westvaco Chlor-Alkali Division, Food Machinery and Chemical Corp., South Charleston, W. Va.

Operator's Responsibility

Without question, the primary duty of a water plant operator is to run the plant correctly [4], and to serve to the city water which is safe, sparklingly clear, free of taste and odor, and reasonably non-corrosive or scale forming. However, each operator is responsible for seeing that all equipment in the plant is in good running order by devoting some of his spare time to the maintenance, or possibly repair, of the equipment.

For instance, the operator should

check pump bearings regularly for overheating; see that filters are adequately washed; make sure that the chlorinator is functioning properly, the dry feeders are in good repair, and the gauges and rate-of-flow controllers are operating; and report to the proper authority any unusual condition of any plant equipment. The maintenance duties of an operator vary according to the size of the plant in which he is working.

Small and Large Plants

In the small plant the operator is usually on his own; he must personally carry out all the general maintenance, from cleaning the plant, to lubrication, to small repairs.

In the small plant there is often a minimum of supervision, so that it is up to the operator to set up his own maintenance schedule. As many small plant operators are burdened with too great a variety of duties, the tendency is to take care of only the most pressing jobs, hoping to do tomorrow the maintenance jobs the plant needs [7]. As a result, more emergencies tend to occur in small plants than in large ones.

The small plant can get valuable assistance from manufacturers' field service men to occasionally inspect, overhaul, or repair pieces of complicated equipment of their own manufacture. Every piece of equipment needs the attention of a specialist at times. Because the manufacturer is anxious to see that his equipment runs efficiently, charges for a field service man are usually held to reasonable figures. This service is especially valuable to the small water plant.

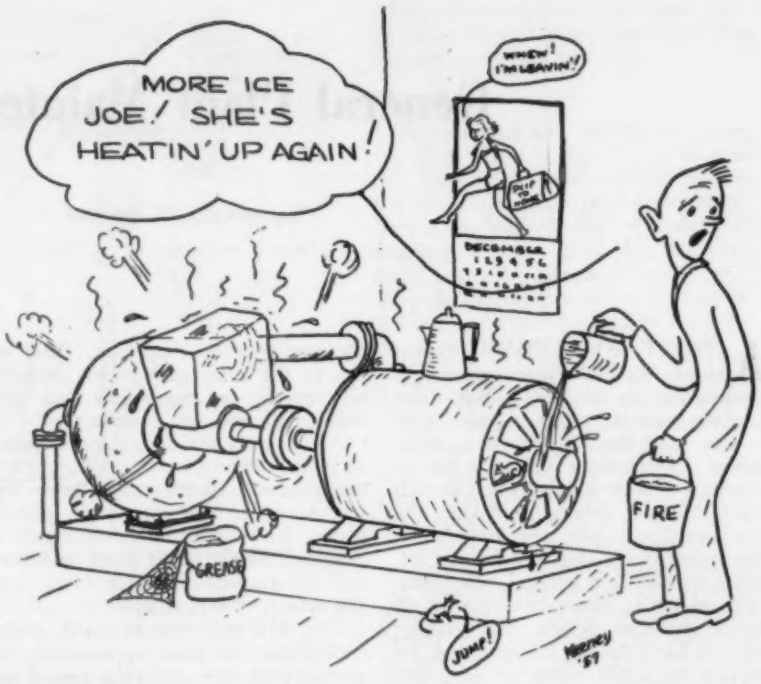
In a large water treatment plant the operator will have assistance in maintenance of the equipment. To begin with, he may have his own assistant, or assistants, who will handle the routine checks of equipment. Competent mechanics are also usually available for repair jobs and maintenance.

Variations between these two cases will be found, according to the size of the plant.

General Principles of Maintenance

Hartung and Weir [7] have summarized the principles of general water plant maintenance of equipment, as follows:

1. Any unusual sound or change in appearance should be investigated. For example, a knock in a gasoline motor, chattering in a centrifugal pump, thumping in an air compressor, or a squeak in a chemical feeder are often early signals of mechanical failure. Obviously, an operator should report any such changes that he notices. During the periodic check-ups made on each piece of equipment, however, the more critical eye and ear of a competent mechanic will often detect operating irregularities which an operator will miss.



2. Equipment must be kept clean. Moisture, dirt, dust, cobwebs, bugs, spilled oil, and so on, are definitely enemies of mechanical and electrical equipment. A vaccum-type cleaner and a compressed air line for blowing out equipment are almost "musts" for keeping equipment clean.

3. Equipment must be protected against external conditions that may cause general deterioration or damage. Open motors should be protected from dust; machinery requiring the dissipation of generated heat should be ventilated; and equipment which would be harmed by water should not be located near potentially leaking pipes, tanks or fixtures.

4. Metal subject to corrosion should be painted or kept under protective covering, nuts and bolts should be tight, etc.

5. Thermometers or surface pyrometers should be used to check temperatures according to manufacturer's recommendations, or other proven methods.

6. Vibration must be watched, and corrected if excessive.

7. Periodic tests for proper operation should be made. (Example, pump tests.)

8. Equipment must be properly lubricated; that is, with the proper lubricant, properly applied. Over-lubrication is as serious as under lubrication.

9. Wear must be watched for, and corrected if it becomes excessive.

Maintenance of Pumps

Maintenance of pumping equipment is a broad subject in itself, but here again resort is made to the automobile owner to illustrate the operator's responsibility for pump maintenance. Most auto owners are not auto mechanics; but the owner is responsible for keeping his auto in good, safe running condition. He does this by observing his car's condition and by taking it to a competent auto mechanic when anything appears to be wrong. Also, he will have an occasional check-up of his auto, such as before a long trip or vacation, to allow the mechanic to anticipate and repair any potential trouble.

In just the same way the water plant operator must keep pumps under observation and promptly report any findings. The following are some of the ideas of others on pump maintenance from the operator's standpoint:

1. The operator must be impressed with the importance of his responsibility to detect and report irregularities in the operation of a pump [1].

2. Bearing and packing temperatures are of more significance than high temperatures [1].

3. The "old timer's" criterion of whether or not he could hold his hand on the bearing is of little value in terms of modern concepts. A thermometer should be used to determine

temperatures [1]. The question then comes up as to what temperature is safe for a bearing. Lischer [1] is of the opinion that bearings can operate in continuous service at temperatures of 160°F. Many maintenance engineers don't like to have any bearing that hot, however, although present practice is that a bearing can operate safely at 50°F above room temperature.

4. When sleeve bearings are used, lack of proper lubrication will result in excessive bearing wear. Therefore, care should be exercised by the operator to ascertain that the oil in the sleeve bearing is at the proper level and to determine at frequent intervals whether or not the bearing oil rings are rotating [2].

5. If ball or roller bearings are used, the operator must overcome the natural tendency to over-oiling to prevent the high temperatures which result from the thrashing of the lubricant, particularly at high speeds. Where grease is used as a lubricant it is also possible to cause high bearing temperatures by over-dosing [2].

6. Changes in the sound of a running pump should be investigated immediately [1]. Changes in pressure or flow in the pump discharge are often an indication that something is wrong with the pump.

7. Some authorities recommend a periodic complete disassembly and overhaul of pumps, the period ranging from once each year for some raw water pumps to once in five years for finished water pumps. [1]. Others take the view that while a pump is running O. K. it should be left alone, except for routine care.

Maintenance of Motors

Dirt causes more failures in motors than any other single factor. Open-type motors should be frequently blown out with air at approximately 15 psi pressure [8]. The maintenance engineer of the author's company suggests that motors be blown out once a year. However, care must be used in blowing out a motor so that none of the accumulated dirt is blown into the bearings, as even a slight amount, especially in ball bearings, can ruin them very quickly [8].

Maintenance of Filters

Filter maintenance is the operator's prime responsibility. Although a filter could scarcely be classed as a delicate piece of equipment, it can be ruined quickly by improper washing or lack of proper care. A few years ago the author received a long distance telephone call from the mayor of a small city who wanted to know where he could buy good filter sand. He said that his city had just bought new filter sand, which he said was no good. Knowing the supplier and the filter sand they furnished, the author assured him that this company's sand was as good as any. "Well", he said, "nearly all of the sand has been washed away already." It developed that this plant was washing filters off the elevated tank in the distribution system and, obviously, too high a wash water rate was being used. The mayor was advised to consult a good engineer before more sand was purchased.

A few years before that, the author was called to a swimming pool where the complaint was that they could not keep the water in the pool clear. A glance at a glass of water from the pool showed a perfect floc. This meant only one thing—a crack or hole in the filter. When the pressure filter was opened for inspection, there was a "rat hole" about two inches in diameter right down through the middle of it. The operator was advised to rebuild his filter. In this case, the filter was washed under city pressure and some of the sand had washed away.

Some of the troubles which can be encountered in filters are (a) mud balls, which if not removed can form a compact mass of mud from the gravel to the top; (b) air binding; (c) mounds and craters on the sand surface; (d) cracks in the sand; and (e) coated sand grains.

Mud balls are formed by the gradual building up of material not completely removed in washing the filters. They tend to accumulate at or near the surface of the sand at first and usually are small. However, the author has seen mud balls of more than an inch in diameter on the surface of filters. If not removed, the compressive force of filtration causes the mud balls to clump together and form larger masses, which then sink during washing to the surface of the gravel. [4].

Inadequate coagulation and settling will sometimes so overload filters that mud balls are formed. Another cause is inadequate washing of filters. In fact, filters are more often not washed enough than overwashed. Even where wash water rates are adequate and filters are washed enough, mud balls may form if there is no surface wash. Where surface wash is not available, vigorous work with a long-handled rake by the operator during washing will keep the filters free of large mud balls. By probing around in the suspended sand with the rake, the operator can feel any hard spots in the sand. When one is found, it usually can be broken up if the rake is used each time the filter is washed.

At intervals of a year or more the top of the sand on some filters will accumulate some debris which will not wash off. It is good practice to use a broad square shovel and carefully remove this debris and a very thin layer of the top sand, which is thrown away. Boards should be laid on the sand to furnish a firm working base for the workman doing this job. After several such skimmings a little new sand should be restored to the

filter to replace that which has been removed.

In case a column of mud extends all the way to the gravel, the proper procedure is to rebuild the filter. Where this is impossible, the column can be removed with shovels and new sand replaced until such time as a rebuilding job can be done, which should be at the earliest possible time.

Air binding of filters is quite common. It results from a water applied to the filters saturated with air, which tends to come out of solution as the pressure falls a little, deep in the filter bed. An air-bound filter usually is a dirty filter. The filter should be removed from service and the air allowed to escape, allowing the water to become low on the filter sand in order to assist the air to escape. Then the filter should be washed, opening the wash water valve very slowly. If the air continues to rise after the wash water valve is just cracked it should all be allowed to escape before turning in more wash water. Turning wash water into an air-bound filter can cause a rush of water up through the gravel, which will upset the gravel, carrying some of it up into the sand.

Mounds and craters on the sand surface may be caused by an upset gravel bed, or may indicate uneven wash water caused by damage to the underdrain system.

In inspecting a filter it is a good plan to measure the wash water rise, to use a rake to feel around for hard spots in the sand when washing and, finally, to allow the water to filter completely down through the sand. If a crater forms during this filtering down, it indicates an upset gravel bed, which indicates the filter needs rebuilding.

Cracks in the filter sand may appear next to the filter wall or scattered through the sand bed. These appear to be caused by partly dirty sand, which shrinks during filtration. Here, again, the remedy is to keep the filter sand clean by adequate washing.

Wash water used equally varies from 1 to 2.5 percent of the water filtered [9]. In some plants the writer has observed, the wash water must average nearer 5 percent in order to keep the filters clean.

Coated sand grains usually result where a water from a lime-soda softening plant is applied to the sand before stability is reached with respect to calcium carbonate. However, ordinary waters deposit calcium carbonate and black manganese compounds on the sand. These will at times cause the sand grains to increase in size, until an occasional grain is as large as a BB shot. Some filter sands examined by the writer were only 40 percent sand, the remainder being coating.

Acid cleaning of badly coated sands is not economical; it is much cheaper to replace the sand. Sand just stained with manganese can be cleaned with sulfur dioxide.

Maintenance of Control Equipment

Around most water plants there is a variety of equipment, such as float controls for starting or stopping pumps, Venturi meters, rate-of-flow controllers on filters, water level gauges, pressure gauges, etc. [3].

But very few water plant operators will be qualified to repair such equipment. And even if qualified, most of them would not have the time to devote to such an intricate task. However, the operator should keep a check on how such equipment is operating and report any irregularities. Smaller plants will probably have to rely on manufacturer's representatives for an occasional repair or inspection and readjustment of such equipment.

By study and observation the operator will learn much about control equipment and in time may be able to make some adjustments and minor repairs to such equipment.

Maintenance of Chlorinators

Every plant should have duplicate chlorinating equipment, but lacking this the operator should have a good supply of spare parts in order to make rapid repairs.

The room in which the chlorinator is installed should be kept warm, not below 60°F.

Needless to say, the chlorinator should be kept clean and metal exterior parts painted. The manual of instruction furnished with the chlorinator should be studied by the operator until he has mastered the information supplied.

Maintenance of Aerators

If nozzle-type aerators are used, it is often necessary to clean the nozzles of accumulations of debris which have clogged them.

Where a cascade-type aerators are used, it may be necessary to clean them of algae growths.

Tray-type aerators need occasional attention to see that the water is passing all trays, as these can be stopped by growths and scaling from the water being aerated.

Maintenance of Chemical Feeders

Dry feeders should be calibrated and tables or curves prepared so that the operator will have available a guide for setting any desired rate of chemical feed.

Also, dry feeders should be lubricated at the regular intervals recommended by the manufacturer.

The operator should inspect the feeder several times during his shift, or plant run, to see that it is feeding properly, that the mixing chamber is supplied with adequate water, etc.

Maintenance of Settling Basins

The chief factor in maintaining a settling basin is periodic removal of the accumulated sludge. Where there is no mechanical continuous elimination of sludge, the minimum number of times that basin should be cleaned is twice a year. A record of each cleaning should be kept.

In some cases it has been known for an operator to so neglect the cleaning of a basin that it became almost full of sludge. In one case of this kind which came to the writer's attention, the operator lost his job.

Cleaning of the basins more frequently than twice a year is often necessary, and the operator should be alert to the need for cleaning the basin. In some cases, he can measure the depth of sludge; in others, he must base his opinion on other factors, such as past records, the amount of turbidity in the raw water, etc.

Summary

An effort has been made herein to show the water plant operator's responsibility toward proper general maintenance of the equipment under his control. Also, an attempt has been made to indicate where his responsibility ends and that of others begin.

In general, it may be said that a water plant is being properly maintained if the operator can proudly say: "I work here."

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WATER WORKS OPERATIONS

THERE IS plenty of water for all the uses and needs of mankind. Unfortunately, it is not always at the location where it is needed most. The Mississippi River system carries off billions of gallons of unused water daily. Through the Great Lakes system pass more billions of gallons of water each day. Down the Columbia, the Colorado and the great rivers of Canada likewise flow more billion gallons each day. And yet there are vast areas where there isn't enough water for agriculture, industry, or even community life. One of the biggest problems of the water works man is to obtain an adequate supply for the domestic and industrial needs of his community.

Source of Supply

Water is found in the atmosphere, on the surface of the earth and below the surface of the earth. Water in the atmosphere is precipitated and falls to the earth, where it collects in lakes, ponds and rivers that run to the sea, or it sinks into the ground where it is stored or used by vegetation which returns it to the atmosphere. Water from the seas evaporates to help replenish the supply in the atmosphere. Water in the atmosphere and in the seas is not usable directly by man.

Man must obtain his water from fresh surface waters or from the ground. The development, maintenance and protection of water supplies are important functions in water works operations. The supply must be adequate; it must be of a quality that can be treated; and it must be protected against undue contamination. The procurement of water looms large as a problem for water works managers.

Distribution

Of what use is water if it cannot be placed where man wishes to use it? It is the function of a distribution system to deliver water to its point of use. This system will include pipes or conveying conduits that bring water from its source to the consumer. It is customary to refer to a distribution system as the network of pipes and appurtenances which carry the water from a treatment plant or pumping station throughout the community served. Transmission main is the term usually applied to large conduits which carry water from a distant source to a treatment plant or distribution system.

Included as an important part of water works operations are the design, construction, maintenance and operation of transmission mains and distribution systems, including pipes, valves, fire hydrants and storage tanks, either elevated or at ground level. Design will be concerned with proper sizing for desired carrying capacity; construction with main laying; maintenance with prevention or remedies for loss of carrying capacity, tuberculation and corrosion; operation with service connections, meter installations and meter reading. No matter what the size of a community the distribution system is a highly important part of the water works.

Treatment

When the available supply of water is not free of undesirable constituents it must be treated before use. The kind of treatment processes used depends on the nature of the undesirable constituents to be removed. Small amounts of suspended matter can be removed by long sedimentation periods in reservoirs. When waters are more turbid due to relatively large amounts of suspended and colloidal matter, chemicals are added to coagulate the turbidity and sedimentation is provided to allow for natural removal of most of the coagulated turbidity. Filtration through sand will remove practically all of the remaining turbidity.

Bacteria are removed largely by coagulation, sedimentation and filtration. Such bacteria as are not removed by these treatments can be killed by disinfection with chlorine or other agents. Tastes and odors may be removed by treatment with activated carbon or chlorine and sometimes by aeration. If tastes and odors are due to microscopic growths they may be controlled by treatment to kill the organisms.

If the constituents which make water undesirable are dissolved minerals, chemical treatment known as softening is used to remove the offending minerals which are the salts of calcium and magnesium. If iron or manganese are present in undesirable amounts, they too are removed by chemical treatment.

These use of these treatment processes to improve the quality of water is commonly termed water purification, regardless of the number of processes employed. Nearly all water supplies are subjected to disinfection if only as a precautionary measure. Most surface water supplies are coagulated, settled and filtered as well. Some surface and well supplies are softened.

Water purification or treatment is a function of water works operations that require both skill and knowledge. Coagulation, sedimentation and filtration are frequently discussed together, as water purification or treatment. On the other hand, three processes in water treatment are of sufficiently disrelated character that they are treated as separate topics in any discussion of water works practices. These are (1) chlorination, (mainly employed for disinfection), (2) softening, which includes the lime-soda process and the ion-exchange process, and (3) iron and manganese removal.

Other Operations

Other operations in water works include, of course, pumping, flow measurement, instrumentation and control, chemical handling and feeding, coagulation and sedimentation, corrosion control, laboratory control, and maintenance. These are all functional operations that apply to both water and sewage works operations. Material on each of these operations has been presented and discussed in Section IV of this Reference & Data Data Edition of Water & Sewage Works.

Factors In Per Capita Water Consumption

by RALPH PORGES

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MUNICIPAL water consumption will vary as influenced by a multiplicity of factors. Most will agree that the following, among others, have their effects:

1. Climate, encompassing rainfall, temperature, atmospheric conditions.
2. Size of community.
3. Type of community.
4. Cost of water and related effects of metering.
5. Water quality.
6. Availability of water.

Where industrial consumption is large in relation to the over-all water use, it may well overshadow the other variations; the use curve may reflect the business cycles. Breaking down the water uses to the domestic portion only would remove the major business influence, but statistics regarding the household fraction are scarce and probably none too reliable.

This report attempts to isolate some of the variables and to illustrate their effects on water consumption.

Method

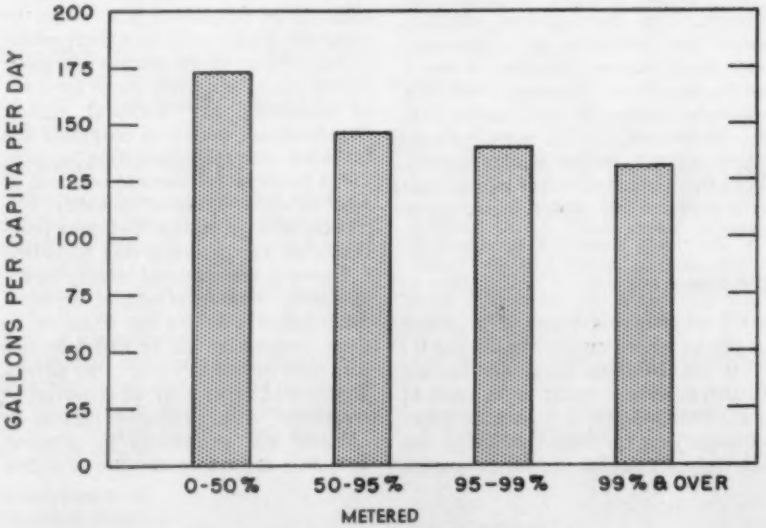
In evaluating statistics of this type it is essential that a large number of entries be utilized to reduce to a minimum the effects of individual variations upon the general trend. In this fashion, reasonable base statistics may be evolved and the major influencing factors detected.

The source data for this evaluation were two municipal water supply inventories [1] [2] issued by the U. S. Public Health Service. These inventories contained data current as of 1954 and included all communities of 10,000 population and over, a 40 per cent sample of communities having populations 5,000 to 10,000, and water districts or companies serving a like population range. Some 1,532 entries were recorded.

The entries selected for the present evaluation included those that provided complete data on population served, average daily output, number of services, and number of meters. In a very few instances, small communities reporting high per capita usage (for example, over 1,000 gpd), apparently resulting from industrial demand, were omitted. The entries that fell within the specified reporting group totaled 1,474.

The statistics were developed to depict water consumption by states, by state groupings, and for the over-all reported data. These have been correlated with various factors to detect relationships influencing the variation in water consumption. To illustrate the effect of community size, the entries were tabulated by population groups as follows: 5,000 to 9,999, 10,000 to 24,999, 25,000 to 49,999, 50,000 to 100,000, and over 100,000. The entries within these groupings were further separated by per cent metered, as follows: 0 to 50 per cent, 50 to 95 per cent, 95 to 99 per cent, 99 per cent and over. To demonstrate regional differences, the states were grouped by geographical areas as established by the U. S. Census:

Area:	States
New England	Me., N.H., Vt., Mass., Conn., R.I.
Middle Atlantic	N.Y., N.J., Pa.
South Atlantic	Del., Md., D.C., Va., W. Va., N.C., S.C., Ga., Fla.



PER CAPITA WATER CONSUMPTION AS INFLUENCED BY METERING

FIGURE 1

TABLE 1

Per Capita Water Consumption, by States

State	Number of Communities	Est. Pop. Served	Water Consumption		Av. Ann. Pecip.,[1] In.
			mgd	gpcd	
Ala.	24	1,395,349	141.55	101	53.00
Ariz.	6	370,030	62.70	169	13.45
Ark.	19	571,325	52.95	90	48.06
Calif.	106	8,987,691	1,400.85	156	23.99
Col.	13	930,812	194.70	209	16.49
Conn.	31	1,740,725	226.03	130	42.36[2]
Del.					42.44
D. C.	1	1,103,000	167.50	152	42.44
Fla.	30	1,782,324	238.33	134	52.76
Ga.	23	1,615,500	199.55	124	50.16
Id.	9	163,773	27.58	168	17.91
Ill.	76	6,690,695	1,282.81	192	36.61
Ind.	55	2,138,814	294.12	138	39.45
Iowa	29	989,265	107.00	108	30.89
Kans.	28	976,520	130.57	133	26.56
Ky.	19	1,075,116	127.58	119	45.45
La.	22	1,465,900	179.52	122	55.22
Me.	16	405,892	53.19	131	42.36[2]
Md.	10	1,900,425	265.19	140	42.44
Mass.	79	3,800,450	431.65	114	42.36[2]
Mich.	57	4,799,571	729.32	152	30.37
Minn.	31	1,359,046	150.08	110	24.99
Miss.	19	575,401	67.75	118	52.86
Mo.	28	2,675,095	371.91	139	40.15
Mont.	8	218,380	46.50	213	14.88
Nebr.	19	610,119	108.69	178	22.30
Nev.	3	111,000	39.10	352	8.81
N. H.	12	280,361	30.50	107	42.36[2]
N. J.	54	3,116,294	437.38	140	45.86
N. Mex.	8	307,500	52.54	171	14.41
N. Y.	98	12,247,551	1,641.87	134	39.45
N. C.	37	1,305,209	143.77	110	49.76
N. Dak.	10	148,900	14.73	97	16.89
Ohio	79	5,622,871	846.30	151	37.73
Okla.	31	1,022,828	131.61	129	31.94
Ore.	21	879,451	127.34	145	26.92
Pa.	108	7,707,185	1,084.79	141	42.33
R. I.	9	740,374	74.27	100	42.36[2]
S. C.	14	667,500	75.92	114	47.69
S. Dak.	9	148,100	22.67	153	18.97
Tenn.	22	1,476,363	181.21	123	49.92
Tex.	87	4,873,578	695.90	143	30.54
Utah	7	349,550	93.75	268	12.63
Vt.	6	93,300	13.00	139	42.36[2]
Va.	21	1,495,997	153.58	103	42.63
Wash.	27	1,404,622	288.16	205	35.18
W. Va.	14	610,317	70.83	116	43.36
Wis.	34	1,787,131	269.36	151	30.57
Wyo.	5	104,700	21.70	207	13.93
Total	1,474	94,844,900	13,567.52	143[3]	

[1]From "Climate and Man—Year Book of Agriculture, 1941."
[2]New England rainfall quoted for each New England state.
[3]Average daily per capita consumption.

East North Central	Ohio, Ind., Ill., Mich., Wisc.
East South Central	Ky., Tenn., Ala., Miss.
West North Central	Minn., N.D., S.D., Iowa, Nebr., Kan., Mo.
West South Central	Ark., La., Okla., Tex.
Mountain	Mont., Wyo., Idaho, Colo., Utah, Nev., N.M., Ariz.
Pacific	Wash., Oreg., Calif.

Results

Table 1 shows state totals, with the number of entries reporting, estimated population served, average million gallons daily use, gallons per capita per day, and average annual state precipitation[3]. A total of 1,474 entries were recorded serving an estimated population of 94,844,900, with an average of 143 gpcd. The state averages ranged from 352 gpcd for Nevada (3 communities) to 90 gpcd for Arkansas (19 communities). The average state precipitation ranged from 8.81 inches per year in Nevada to 55.22 inches in Louisiana.

To depict the influence of population and the effect of metering, Table 2 was developed. Here, all entries are segregated into population groups No. 1 to No. 5 and into the indicated per cent metered categories.

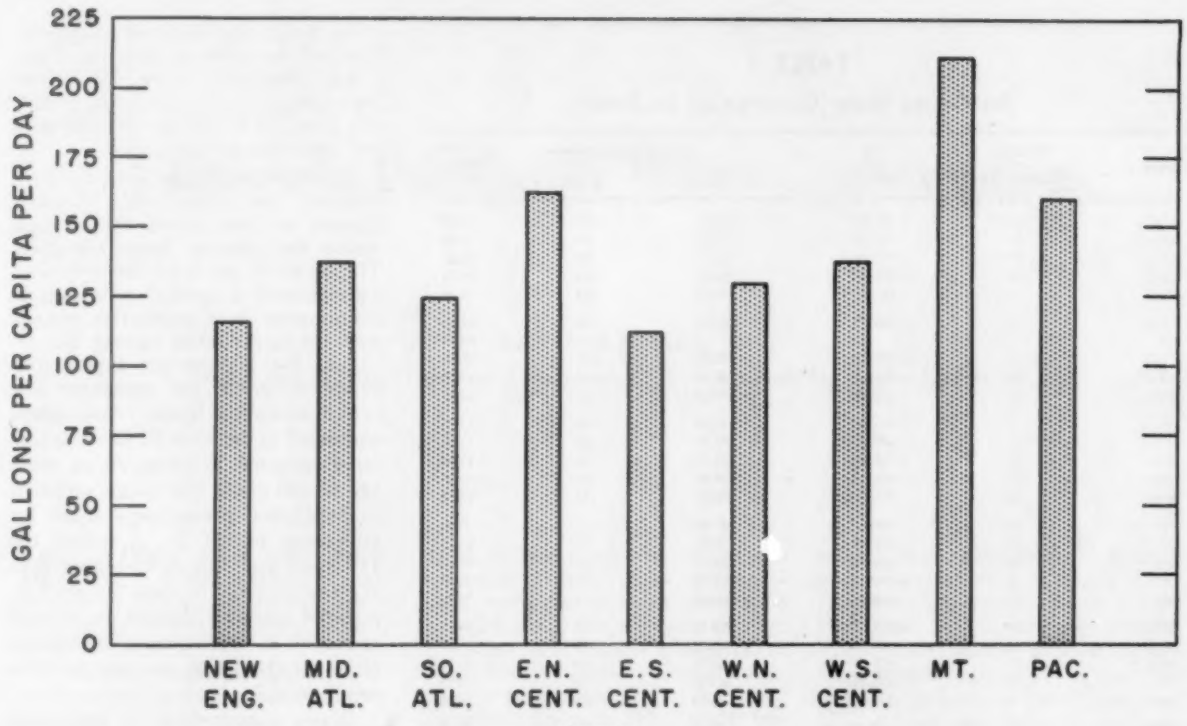
In the 0 to 50 per cent metered category, the population groups showed no firm trend, the average within the category being 174 gpcd. The 50 to 95 per cent metered category showed a marked reduction in consumption in all population groups, with the larger cities (group No. 5) having the highest per capita consumption within the category. The trend towards lower consumption continued in the 95 to 99 per cent metered category, dropping to an average of 140 gpcd. The usage variation in population groups was slight for all groups except No. 5, where the 149 gpcd was 26 gallons higher than the runner up. The over 99 per cent metered category showed an over-all reduction in unit water consumption, although the trend was not uniform in all groupings.

Water consumption by population groups as noted in the composite data was 129 gpcd for group No. 1, 134 for No. 2, 133 for No. 3, 129 for No. 4, 150 for No. 5. The marked increase of population group No. 5, with exception of the 0 to 50 per cent metered category, appears to be consistent and significant.

The composite categorical results show 0 to 50 per cent metered, 174 gpcd; 50 to 95 per cent metered, 146 gallons; 95 to 99 per cent metered, 140 gallons; and over 99 per cent metered, 131 gallons. (See Fig. 1)

Regional summations are depicted in Table 3 and Fig. 2. The lowest average per capita daily consumption of 115 gallons was reported by the East South Central region, followed closely by the New England region with 117 gallons. The highest per capita demand at 211 gpd was recorded by the Mountain region.

In an effort to delimit water usage in accordance with precipitation statistics, Table 4 was developed. The States were grouped in broad precipitation ranges as indicated and the median State value for consumption presented. This showed a downward trend in water use as precipitation increases as is illustrated in Fig. 3. To further limit the data, similar statistics for the domestic consumption were likewise tabulated. An initial trend was detected but it was not consistent.



AVERAGE PER CAPITA WATER USE BY GEOGRAPHICAL REGIONS

FIGURE 2

Discussion

Evaluation of Base Data

One of the principal considerations in the utilization of data is reliability of the initial compilation. The data used in preparing the inventories on which this report is based were assembled originally from previous tabulations developed by the Public Health Service in cooperation with the State Health Departments, the most complete being the 1949 unpublished inventory, and from other available sources. These data were then forwarded to the regional offices of the Public Health Service, from where they were sent to the State Health Departments.

In virtually all instances, the states referred the data to the local facility for check, review, correction, and completion by local officials. The data received reviews at all levels and questionable items were returned to the states and local facility for ultimate clarification. It is recognized that some errors do persist, but it is believed these are minor and do not influence the conclusions. On the other hand, the data represent probably the most reliable information to date.

Another factor of consideration is the equipollence of comparative statistics. In all instances are statistics of equal value being utilized. It is necessary to consider, when comparing gross per capita consumption values, the number of communities reporting and the population grouping, and to recognize inherent differences that may occur.

It has been estimated[5] that about 17,000 communities in the United States in 1954 had public water systems serving approximately 115,000,000 people. The 1,474 communities of this study represent nearly 9 percent of the municipalities and 83 percent of the total estimated population served. The per capita consumption of the sampled group was 143 gpd. This compares with 149 gpcd reported for 570 communities of 25,000 population and greater, and an estimated 140 gpcd for all 17,000 public water supplies[5]. Again it is cautioned that these variations are probably due to population selection.

Comparison of 1948 and 1954 Inventories

The following depicts comparative water consumption by stated population groupings in 1948[6] and 1954:

Pop. Group	Average Demand, gpcd 1948[6]	1954
5,000 — 9,999	114	129
10,000—24,999	123	134
25,000—49,000	127	133
50,000—100,000	121	129
Over 100,000	157	150
Total	142	143

The average water consumption in 1948 was 142 gpcd, whereas the 1954 average was 143 gpcd. It is interesting to note that in 1948 the water consumption of the smaller communities (5,000 to 10,000 population) was 114 gpcd as compared to 157 gpcd in communities of over 100,000 population. The 1954 statistics indicate an increase in the water consumption of the smaller communities, but a reduction in the largest population group. This may be significant and indicate a leveling in water consumption of communities. Decentralization of industry definitely would hasten this trend. The use of municipal water by industry has been pointed out by Picton[7], who states that 20 percent of the manufacturing industry is served by public systems.

In 1948 the population group 5,000 to 100,000 reported an average consumption of 122 gpcd, whereas sim-

TABLE 2

Municiple Water Consumption by Percent Metered and by Population Group

Code Number	Municipalities 1	2	3	4	5	6
Population Group	5,000-9,999	10,000-24,999	25,000-49,999	50,000-100,000	Over 100,000	Total
Metered 0-50%						
Number	51	72	18	8	11	160
E.P.S.*	441,467	1,452,224	794,761	965,261	15,374,760	19,028,473
A.D.O.	80.47	273.76	165.81	187.47	2,611.45	3,318.96
Gpcd	182	189	209	194	170	174
Metered 50-95%						
Number	53	76	36	15	14	194
E.P.S.	506,780	1,485,941	1,603,109	1,314,048	8,077,747	12,987,625
A.D.O.	62.63	191.55	209.75	179.52	1,255.50	1,898.95
Gpcd	124	129	131	137	155	146
Metered 95-99%						
Number	38	55	37	17	24	171
E.P.S.	312,864	1,013,859	1,879,367	1,732,936	9,830,772	14,769,798
A.D.O.	38.03	121.73	231.26	211.42	1,464.24	2,066.68
Gpcd	122	120	123	122	149	140
Meter over 99%						
Number	211	434	159	79	66	949
E.P.S.	1,882,772	7,984,950	6,814,232	7,209,252	24,167,798	48,059,004
A.D.O.	223.85	1,017.17	870.89	865.45	3,305.57	6,282.93
Gpcd	119	127	128	120	137	131
Total						
Number	353	637	250	119	115	1,474
E.P.S.	3,143,883	11,936,974	11,091,469	11,221,497	57,451,077	94,844,900
A.D.O.	404.98	1,604.21	1,477.71	1,443.86	8,636.76	13,567.52
Gpcd	129	134	133	129	150	143

*E.P.S. = Estimated population served; A.D.O. = Average daily Output; Gpcd = Gallons per capita per day.

ilar 1954 statistics showed 132 gpcd, yet the group over 100,000 population dropped from 157 to 150 gpcd. Thus, it must be concluded that, on the average, consumption in communities less than 100,000 population had increased slightly, in communities greater than 100,000 consumption had decreased slightly, and the overall average, based upon these statistics, showed little change.

However, probably even more important is the fact that in communities over 10,000 population (all communities in this grouping included in both 1948 and 1954 inventories) the estimated population served increased 60 per cent in the short span of six years as result of increase in population and servicing of suburban areas, and the total water demand showed a corresponding increase.

The reduction of per capita water use in communities may result from temporary climatic influence, better plant and system management, and conservation measures, particularly in industrial processing. An effective leak detection program, stepped-up plumbing inspections, and metering is reported[8] to have reduced water waste in Chicago by 390 mgd. From 1930 to 1954 the average consumption per person was reduced from 300 gallons to 234 gallons. There would appear to be room yet for additional savings in waste water.

Others have reported trends that appear contrary to the foregoing. No doubt, local conditions play the all-important role. For example, Poole[9] reports for Indiana that water consumption is increasing at the rate of 2.1 gallons per person per year, and that in cities above 100,000 the rate of increase is 3.3 gallons per year while in cities between 25,000 and 100,000 the increase is 2.3 gallons per year.

Water Companies

It was noted that entries not communities as listed in the United States Census (such as water districts, county systems, and water companies serving a group of communities) reported relatively low consumption figures. An average of the 71 reporting was 114 gpcd as compared to the total average of 143 gpcd. Because these entries may serve areas not classified as urban, the low per capita consumption might result from the lack of industry in rural areas.

Effect of Metering

Metering seemed to have a pronounced effect. Generally, per capita water consumption was downward as per cent metering increased. For example, in group No. 1 the range was from 182 to 119 gpcd; the totals ranged downward from 174 to 131 gpcd. On the basis of these data, 100 per cent metering of unmetered supplies would result in water savings exceeding 25 per cent. Others have noted similar savings in specific instances. It was reported[10] in 1938 that Jackson, Miss., had experienced a 30 per cent decrease in water consumption statistics from numerous individual cities also indicates that metering tends to control water consumption. Yet some communities experiencing expanded industrialization have shown increasingly larger per capita water use even though 100 per cent metered.

Regional Influence

Table 3 depicts municipal water use by regions. This type of breakdown brings out the influence of climate and industrialization. The humid east (New England, South Atlantic, and East South Central groups) reported an average consumption of 125 gpcd or less. The Middle Atlantic, West North Central, and West South Central groups reported per capita daily consumption from 131 to 137 gallons. The Pacific states showed 161 gallons, East North Central 163, and the Mountain states 211.

The influence of industrialization may be assumed to have raised the water needs of the East North Central states, whereas the dry climate of the Mountain states also increased water consumption, probably as result of irrigation and air conditioning demands.

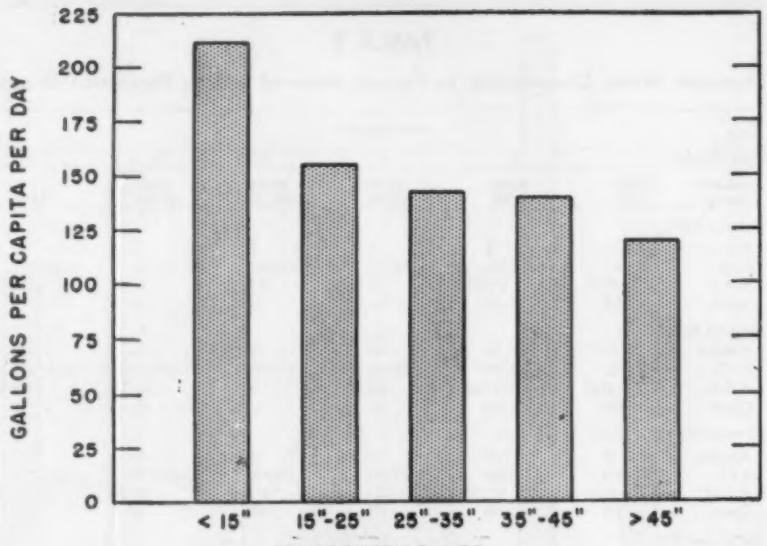
In an effort to more clearly evaluate climate, the states were considered according to increasing annual average precipitation (precipitation values shown in Table 1). Nevada, the lowest state with 8.81 inches of rain, reported the highest per capita consumption of 352 gallons per day. Utah, second with 12.63 inches, reported 268 gallons, the second highest. The trend thereafter was not consistent, although generally downward. However, the most humid states, being in the South, also are the states with the highest temperatures, which may cause greater water use resulting from air conditioning demands.

Table 4 gives a brief summary of these results. With the six states having rainfall of less than 15 inches, the median consumption was 210 gpcd. The trend shown is downward, so that with the eleven states having rainfall greater than 45 inches, the consumption was 119 gpcd.

Only 162 communities reported on the domestic portion of their water consumption. These statistics are included in Table 4. Of five states reporting less than 15-inch rainfall, the median domestic consumption was 92 gpcd. The consumption dropped sharply to 55 gallons in the 15- to 25-inch rainfall group, but no firm trend thereafter is indicated. For eight states having rainfall exceeding 45 inches, the per capita domestic consumption was 64 gpcd. As previously mentioned, high temperatures of the humid states may have caused this increase in consumption.

An additional evaluation of the reported domestic consumption statistics showed[11] that within each population class-percent metered cell, those cities in the lowest precipitation group (10 to 25 inches per year) had the highest domestic consumption. However, there were no consistent differences in domestic consumption among the other precipitation classes.

An interesting method of analyzing the effect of weather and climate on water consumption of a given community has been presented by Leadbeater[12]. He devised a formula that provides for rainfall, temperature, relative humidity and number of wet days, and claims that rainfall is the factor having the most influence; the lower the rainfall, the greater the consumption. The data herein tend to confirm this reasoning.



PER CAPITA WATER CONSUMPTION AS RELATED TO PRECIPITATION

FIGURE 3

Summary and Conclusions

Municipal water facility data as of 1954 from 1,474 community entries having 1950 United States Census populations of 5,000 and greater and were analyzed to indicate some factors that may influence average daily per capita water consumption. Other pertinent items and comparisons are noted.

The following conclusions may be drawn:

1. The average daily per capita demand for the 1,474 entries serving 94,844,900 persons was 143 gallons in 1954.

2. The population of the community affected the consumption. The 5,000 to 100,000 population group averaged 132 gpcd. The consumption of cities over 100,000 population was higher, at 150 gpcd.

3. Water districts and water companies serving groups of communities reported a low consumption of 114 gpcd.

4. The average demand of entries with populations ranging from 5,000 to 10,000 was 122 gpcd in 1948, as compared with 132 gpcd in 1954. In cities over 100,000 population, the demand was 157 gpcd in 1948 and 150 gpcd in 1954. Considering all municipalities over 5,000 population, the average consumption was 142 gpcd in 1948, as compared to 143 gpcd in 1954.

5. During the short period of 6 years (1948 to 1954) the estimated population served by municipal water systems of communities having populations greater than 10,000 increased 60 per cent, with a corresponding increase in water consumption.

6. The average per capita municipal consumption decreased as the per cent metered category increased. It appears that metering of a water supply might result in an over all reduction in unit water use of over 25 per cent.

7. Regional grouping of statistics brought out the variations in the several parts of the country. The East South Central states were lowest, with 115 gpcd; the Mountain states were highest, with 211 gpcd. The industrialized East North Central states were second highest, with 163 gallons, followed closely by the 161 gallons of the Pacific states.

8. The average per capita consumption for states ranged from 353 gpcd for Nevada to 90 gpcd for Arkansas.

TABLE 3

Per Capita Water Use by Geographical Regions*

Region	No. of Communities	Population Served	Consumption mgd	gpcd
New England	153	7,061,102	828.64	117
Middle Atlantic	260	23,071,030	3,164.04	137
South Atlantic	150	10,480,272	1,314.67	125
East North Central	301	21,039,082	3,421.91	163
East South Central	84	4,522,229	518.09	115
West North Central	154	6,910,045	905.29	131
West South Central	159	7,933,631	1,059.98	134
Mountain	59	2,555,745	538.57	211
Pacific	154	11,271,764	1,816.33	161
Total	1,474	94,844,900	13,567.52	143†

*U. S. Census regions.
†Average.

Those states with the lowest annual precipitation reported the highest per capita demand. There is a tendency for the per capita consumption to decrease as the annual precipitation increases.

9. Domestic water use was high (92 gpcd) in states having less than 15 inches annual precipitation. The domestic consumption decreased to 55 gpcd in states with annual rainfall ranging from 15 to 25 inches; with increasing rainfall the demand showed but slight variation.

TABLE 4

Water Consumption in Gallons per Capita per Day as Related to Precipitation

No. States Reporting	No. Communities Reporting	Precipitation, State Average,	Water Consumption, Median of State Average,
(a) TOTAL MUNICIPAL WATER CONSUMPTION			
6	37	< 15	210
7	197	15 — 25	156
7	287	25 — 35	143
17	670	35 — 45	139
11	283	> 45	119
48	1,474	30*	139*
(b) DOMESTIC MUNICIPAL WATER CONSUMPTION			
5	6	< 15	92
7	25	15 — 25	55
7	38	25 — 35	57
12	63	35 — 45	42
8	30	> 45	64
39	162		

* Average.

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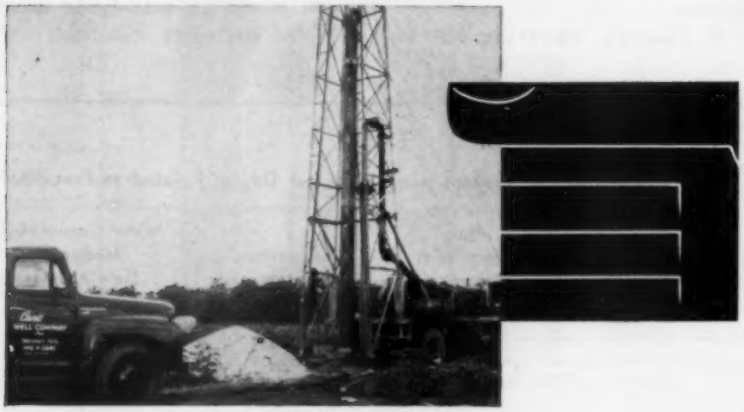
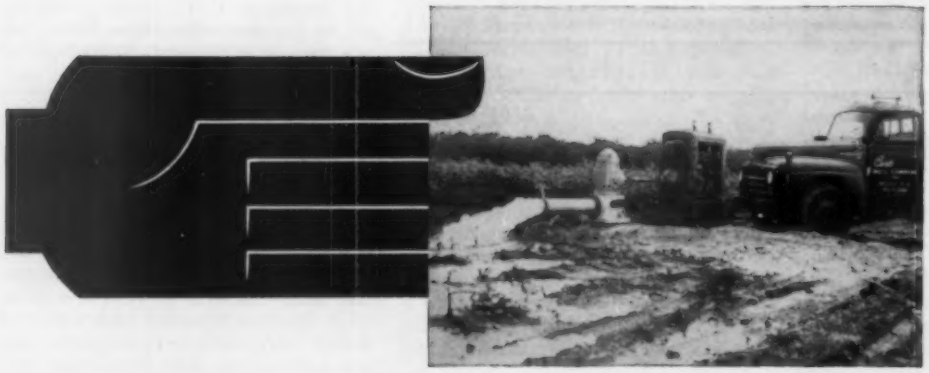
PICTURE OF A WISE WELL DRILLER 20 feet of 12" (#60) slot Red Brass Wire Wound Cook Well Strainer are lowered into a 120' Well drilled by Cart Well Co., Inc., Weiner, Ark.



PICTURE OF HIS REWARD

2000 gallons per minute for irrigating the cotton and soy bean farm of Billy Flippo near Turrell, Arkansas. The Cook strainer produced this water with less than 25 feet of drawdown.



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Elements in Water Supply Development

by JAMES W. MYERS, JR.

Vice-president and Chief Engineer of the Philadelphia Suburban Water Co., Bryn Mawr, Pa.

SOUND, long-range planning for water service is a never-ending undertaking. It can never be static.

Unfortunately, however, hundreds of well-conceived long-range plans, in beautiful leather-bound covers, are statically gathering dust, while communities resort to day-to-day stop-gap measures, which are never completely satisfactory or economical. The long-range plan, although fundamentally sound in its concept, also must be flexible enough to permit modifications in the construction time-table to meet changing water needs, or to take advantage of a favorable money market, or to temporarily hold projects in abeyance if times and conditions are not favorable to their execution.

Water Needs

For several years the technical publications have carried literally hundreds of discussions seeking to define reasonable water service. According to Wolman[1], "These efforts at definition have ranged from the hope that reasonable water service would mean providing water for all parts of the land, for all requirements, at all times, to definitions which rest rigidly upon a service of limited character, dominated primarily by the inflexibility of existing water rate policies," He concluded that "neither of these extremes was likely to produce the best values to the customers."

We have no quarrel with the water works officials and the public who put the emphasis on improved service, rather than rates. But the prudent water works official must insist on a proper balance between development costs and rate of return.

Analysis of the title of this paper word by word shows three basic elements to put in balance; namely, economics, engineering, and need. It is a provocative title, and undoubtedly creates totally different meaning for each reader.

At the risk of ever-simplifying the definitions, "engineering," to the author, means the conception of a project, the design and construction of the structure, and its operation. "Economics" is the science of business. "Need" is the necessity for, or urgent want of; and in this case, the need is for an abundant and dependable supply of potable water.

In further analyzing this topic, it seems impossible to disassociate the two words "economic" and "engineering." Usually they appear in reverse—as engineering economics.

One text book definition states: "Engineering economics deals with the elements of cost of service performed by the engineering structure, the elements of revenue, the inter-relations of these elements, and their resultant effect upon profit"[2].

With few exceptions, the choice of any engineering structure and the design of the component parts, as well as the whole, is finally judged from the economic standpoint. It naturally follows, then, that the so-called principles of design are subordinate to the principles which underlie economic judgment.

But how can water works management control or compromise on the need for water? After all, the need for water is beyond management's control. It is established by customer habit and use, and by changing times and conditions.

The whole planning problem at Philadelphia Suburban Water Company is fundamentally one of forecasting water needs and weighing and balancing engineering and economic considerations to satify those needs. The future public need for water is determined by more or less well-established methods of forecasting based on past consumption, customer accounts, population, etc.

However, these methods of forecasting, although following a somewhat universal pattern, must be tempered by judgment and adapted to local peculiarities and growth patterns.

Growth in Service Area

The growth pattern in the Philadelphia Suburban area shows some striking facts. In fact, these lead to an observation or two which seem to contradict the mass of evidence which indicates a universal increase in per capita or customer consumption. During the last decade more than 58,000 customers have been attached to the company's system, an increase of 59.9 per cent.

There is a strong probability that the rate of customer growth in these last few years will not continue. The Census Bureau, viewing the national population trend, has estimated that "by 1960, new households will come into existence at an annual rate of only 40 per cent of the 1948 rate."

*This paper, presented before the Pennsylvania Water Works Ass'n., is printed by permission of the Association.

"The prudent water works official must insist on a proper balance between development costs and rate of return."

The future is, however, conjectural, and whether or not a specific community follows the national trend depends on local conditions peculiar to that area. For instance, the charter territory of this company, being adjacent to the nation's third largest city in the Delaware Valley industrial area, is particularly adapted to the decentralization needs of business and industry. As a result, numerous commercial organizations have established their entire operations, or important branch operations, in the territory within recent years. Moreover, in addition to these laboratories, manufacturing plants, commercial and industrial office buildings, large garden-type apartment houses, modern shopping centers, and branches of large metropolitan department stores also have appeared in the suburban Philadelphia area.

Basis of Forecasting

The forecast of future water needs for the suburban area served by the company is predicted almost entirely on the rate of increase in customer accounts. More than 96 per cent of the accounts are domestic, requiring 78 per cent of the total pumpage; it is significant that the ratio of domestic consumption to total consumption remains virtually unchanged. In making forecasts of future water demand, the company has found that the average daily use per customer account is a most reliable yardstick. As evidence of its reliability, it should be pointed out that during the past eight years the average daily use per customer account, which includes all classes, ranged from 282 to 288 gallons. This is a variation in use of only 2 per cent. Moreover, during the depression year of 1933, the use per customer account was 280 gallons per day.

The system average fails to reflect the increase in per capita or customer use that has been given such wide publicity. In further support of this conclusion, it is pointed out that the 58,000 accounts added to the company's system during the past decade were added during the period when automatic washers, home air-conditioners, kitchen garbage grinders, etc., became available to the home builder. It seems logical that with the addition of such a large number of completely modern homes, equipped with these labor saving devices, the consumption per customer would have reflected the presumably universal increase in per capita use.

In analyzing consumption by meter districts, there is found some fluctuation in the use pattern. But the system average used for forecasting the total requirements from new sources of supply has not materially changed in the past 25 years.

"Sound long-range planning for water service is a never-ending undertaking. It can never be static."

The company's experience seems to indicate that the increase in demand from 24.8 mgd in 1945 to 42.7 mgd in 1955 is directly related to the increase in the number of customers, rather than to a change in use habits.

The ratio of the average day to the peak hour has increased somewhat, but peak days are still less than 150 per cent of the average day.

Although an analysis has not been made of individual districts, there seems to be little question that the 3-hour and 6-hour peaks in certain districts could approach the lawn sprinkling peaks of 200 to 400 per cent reported in the April 1956 issue of the *A. W. W. A. Journal.*

In forecasting future water needs, we are primarily concerned with average daily demand, rather than the peak day or peak hour. The capacity of the pumping station, purification works, and transmission mains must be capable of meeting the peak day requirements, and the combination of these, together with distribution storage, must meet the peak hour demand. The economic, engineering and public need balance for providing these facilities is somewhat different than that which concerns itself solely with the source of supply.

Extent of Future Development

Having established a basis for forecasting the public need, what is the extent of a development to be undertaken at any one time? An alert management must not only keep abreast of current problems, but also keep ahead of the problems of the foreseeable future.

The prudent water works designer will project his forecast at least 25 years, and will attempt to provide for that demand by incremental or step construction, if at all possible. It is not advocated that facilities be ready 25 years in advance, but merely that the forecast be projected to this point.

Water works management must know what sources will be available for future development. Moreover, management must have a fairly accurate estimate of the time required to overcome all legal hurdles and allied problems incident to the development of a given source.

Sources of Supply

A water works property which can secure its supply from the Great Lakes or a large river, such as the Delaware or Schuylkill, needs only to install lake or river intakes as needed, and proceed with an orderly step development of the facilities required for processing and delivering the water to the customer. Unfortunately, few are blessed with such inexhaustible supplies, most are under the necessity of developing rural streams and tributaries, requiring the costly construction of dams and impounding reservoirs. Water works properties having a good potential of high quality ground water will find it most economical to develop deep well systems.

Friel has presented a tabulation of some 13 supplies, and compared the cost of these several projects on the basis of capital investment required per million gallons per day. There were eight surface supplies, with varying construction problems, ranging in cost from $118,000 to $510,000 per mgd, as opposed to five deep well developments which ranged in cost from $12,200 to $35,300 per mgd.

The water works management having both surface and ground water sources available would have no problem in economic choice. However, the basic question as to the extent of the development to be undertaken at any time is not always one of economic choice. More often, it is the availability of a source of supply.

With ground water sources and deep well development, it is not necessary to construct facilities too far in advance of the actual need, since wells usually can be developed and brought into production in a relatively short time. Consequently, a progressive expansion program can be undertaken which will keep construction just a few years ahead of

"With few exceptions, the choice of any engineering structure and the design of the component parts, as well as the whole, is finally judged from the economic standpoint."

"The forecast of future water needs for the suburban area is predicated almost entirely on the rate of increase in customer accounts."

actual need. Thus, with the opportunity for this type of incremental development, the actual construction can be closely keyed to the changing conditions.

Surface sources of supply, on the other hand, require dams and impounding reservoirs, thereby posing a totally different problem. When it is economically feasible to do so, a dam should be constructed to develop the full reservoir site capacity. Under these circumstances, the collection works may be considerably over-built and must be carried by the company, or the present rate payers, until such time as the full capacity is needed.

Based on recent experience in the development of a surface supply on Upper Perkiomen Creek, it has been found that delays incident to the acquisition of land, the vacation and relocation of roads and bridges, and the endless legal obstacles, make it almost impossible to set up a normal construction time-table and normal economic considerations.

Green Lane Reservoir Development

The Green Lane reservoir development had its inception in 1929, when the company purchased approximately 430 acres of land in Upper Perkiomen Valley, near Green Lane, about 17 miles upstream from the confluence of Perkiomen Creek and the Schuylkill River. This parcel of land, because of its location in the narrow portion of the valley in the Brunswick formation, is an excellent dam site. The drainage area above this point is a fan-shaped watershed of some 71 square miles.

At the time the company acquired this property its immediate development as a source of supply was not contemplated. In fact, it was not until February 1950 that application was made to the Pennsylvania Water and Power Resources Board for a permit to supplement the amount of water then being taken from Perkiomen Creek in Montgomery County.

From the day the permit was filed, the company was faced with persistent opposition, causing unnecessary and costly delays that nearly jeopardized the supply to thousands of innocent water consumers.

In the company's first appearance before the Board, it was made abundantly clear that the proposed development would not only satisfy an urgent need for water for public water supply purposes, but the operation of the reservoir and the resultant regulation of the stream flow would greatly improve conditions along the creek. In addition to the creation of a beautiful lake in the heart of the Upper Perkiomen valley, the regulation of the reservoir would increase stream flows during periods of low flow and would tend to minimize flood flows. Consequently, the development would operate to the benefit of all downstream riparian owners.

Numerous meetings were held with local service clubs and citizen groups in the valley in an effort to acquaint the people with the project. Despite the company's best efforts, however, a small but vocal opposition group was formed.

Coincident with the efforts to win the support of the people in the valley, hearings were held before the Water and Power Resources Board. Finally, in January 1951, almost one year from the date of application, a permit was issued for the additional allocation.

In a matter of weeks, the opposition filed an appeal from the action of the Board. This resulted in an amended permit, issued June 27, 1951. But it was not until April 15, 1952, approximately 26 months after the filing of the application for the allocation, that the company was finally in a position to apply to the Board for a permit to build the dam.

Within one month after the filing of the dam permit, certain municipalities and owners of land on the Perkiomen Creek watershed petitioned the Board to review its previous proceedings and re-open and rehear the case. After three more tedious hearings, the Board on April 8, 1933, reaffirmed its water allocation to the company, and on August 12, 1953, approved the company's application for a permit to build the dam.

The over-all project contemplated a gravity section, concrete dam and a 4,400-mg. impounding reservoir. The dam was to be 782 feet long, including a 424-foot spillway; the breast, 87 feet wide across the base and 82 feet in height; the normal water depth behind the dam, 66 feet; the area of the lake approximately 814 acres, with about 17 miles of shore line. The reservoir was to provide a maximum safe yield of 16.5 mgd.

In the operation of the reservoir, releases of impounded water will be made in regulated quantities and allowed to flow 17 miles down the stream, where it will be recaptured and pumped 2½ miles to the company's Pickering Creek pumping station and purification works for treatment and delivery into the system.

Immediately following the issuance of the permit to build the dam, the opponents filed a complaint in equity seeking to have the court enjoin the company from proceeding under the water allocation and dam-building permits. On January 28, 1954, the court sustained the company and dismissed the complaint. The opposition continued its fight by taking an appeal to the Pennsylvania Supreme Court. After another hearing and reargument, the appeal was denied and the case finally cleared the courts on June 24, 1954, approximately 4½ years after the filing of the application.

Despite these delays, the company had proceeded, in so far as was practicable, with the preparation of detailed plans, specifications, and contract documents for the dam structure.

Looking back on these hectic proceedings, it seems almost incredible that a worthwhile undertaking by a reputable public water supply agency should meet with such unwarranted and sustained opposition.

Bids for the dam structure were received on September 1, 1954, and the contract documents signed on October 4.

But the troubles were by no means over. Notwithstanding the fact that most of the properties required for the development were secured by negotiation and amicable settlement, there were many transactions in which differences could not be resolved, and the company was compelled to exercise its right of eminent domain to secure immediate possession and keep the project moving more or less on schedule.

One of the most time-consuming problems related to the vacation of eight rural roads, which were to be flooded on filling the reservoir. These negotiations required five special meetings with township supervisors and two public hearings, which began November 11, 1954, and terminated December 13, 1955.

This recital of the multiple and unpredictable delays has but one purpose: to point up the fact that prudent management must make proper allowances in its time-table of construction to provide for interminable

delays. Although the actual time required to build the dam will be less than two years, the total time from the filing of the application to the completion of the project will have been seven long years.

A Special Problem

One element of cost in this development which highlights the difficulty of trying to balance engineering, economic and public need elements was the preservation of a county road over the reservoir area.

Because of the small volume of traffic using the road, and the limited capacity of an old covered bridge carrying the roadway over the creek, the company had every expectation that the road would be vacated in exchange for a modern substitute road carrying traffic around the reservoir. This substitute road would satisfy the engineering problem of getting the traffic from one side of the reservoir to the other, and would also satisfy the economic requirement of getting the job done at the lowest possible cost.

Rather than review in detail the legal problems which this road imposed, the economics involved are briefly mentioned.

Careful traffic studies showed that a capital expenditure of approximately $65,000 was all that could be justified in keeping the old road open. The estimate cost of the substitute road was $100,000, as compared to an estimated cost of $500,000 to raise the road and bridges and maintain the existing location.

However, a Jury of View found that the road should remain. Despite the company's best efforts to balance engineering, economic and public need elements, it was obliged to spend additional capital which was badly needed for other worthwhile capital improvement projects.

"If water works are forced to make capital additions, which, in turn force an increase in rates to the extent that consumption is curtailed, they may well be approaching an economic limitation."

Economic Limitations

The economic limitation on the extent to which a water company can go in providing for expansion is largely predicated on net income.

Whether funds for capital additions are to be provided through bank loans, bonds, or stock, the investor must be assured of a satisfactory return on his investment if he is to be induced to invest in one business, rather than in some other. Management's desire to keep a utility financially strong is frequently questioned by certain water consumers who feel that the utility need only ask for an increase in rates to cope with its financial problems.

The demand for new capital seems to go on unabated. In the ten year period ended December 31, 1955, the Philadelphia Suburban Water Company spent more than $39,000,000 for needed capital additions and attached 58,000 new customers. This is equivalent to $675 per new customer.

The investment in plant per customer account in 1945 was $242, and steadily climbed to $405 by the close of 1955. What could be more pertinent to the subject of water works economics? In considering these figures, the 80 percent increase in the construction cost index during these ten years must be borne in mind.

In the light of increasing costs for plant expansion and the consequent need for higher water rates, the questions should be asked whether water rates can go too high, and what, if any would be the consequence?

In 1926, Metcalf[3] published the following table showing the relation between demand and cost of water:

% Increase in Cost of Water	% Decrease in Consumption
20	13
40	22
60	29
80	35
100	40

Although times and conditions have drastically changed, Metcalf's findings of 1926 may still apply.

By no stretch of the imagination could this be considered a conclusive answer to the question, but it does indicate that if water works are forced to make capital additions which, in turn, force an increase in rates to the extent that consumption is curtailed, they may well be approaching an economic limitation.

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Distribution System Extension

by RAY MURRAY

Principal Engineer, Nussbaumer, Clarke and Velzy, Consulting Engineer, Buffalo, N. Y.

EVERY COMMUNITY, large or small, which has a water system, will be confronted, sooner or later, with the problem of making extensions thereto. The problems presented by extensions fall into two general categories. First is the problem of the policy or procedure to follow in making extensions, and secondly the problem of mechanics of installing the extension. This paper will deal in generalities as to the policy or procedure in making extensions; but will cover in more detail the mechanics of installing them.

Policy

The "Conservation Law" of the State of New York has the tendency to subdivide water system extensions into two classifications. One class being those extensions to be made within the corporate limits of a municipality or water district. The other class are those extensions to be made outside the corporate limits of a municipality or water district.

In the first instance, the governing body of the municipality or water district has the authority to approve and authorize the construction of any extension within its corporate limits. In the second instance, where the service extension is to be made beyond the corporate limits of the municipality or water district, the Conservation Law requires that an application be made to the Water Power and Control Commission, and that its permission be granted before any extension is made to the desired water service area.

Copies of the New York State rules and regulations for making application for extensions under the jurisdiction of the Commission, may be obtained by writing to the Water Power and Control Commission, 110 State Street, Albany, N. Y.

Engineering Study

Regardless of whether the jurisdiction to make extensions rests with the municipal authorities or with the Water Power and Control Commission, the problems presented in making extensions are the same. In either case an engineering study should be made. This study (excluding the need for storage, pumping stations, etc.) should cover the following basic points:

1. A determination of the present and future water requirements of the area to be served by the extension, including fire demand.

2. The adequacy of the existing water facilities and distribution system to meet the demands imposed by the extension.

3. The integration of the extension into the existing distribution system.

4. The size of pipe, location of valves and spacing of hydrants required to satisfy demands of the proposed extension and any future expansion thereof.

5. Materials to be used in construction.

All too frequently a municipality or water district will contract to make extensions into new areas without first studying the demands of the new extension and its effect upon the existing water producing and distribution facilities. This action often results in an overtaxed system and poor service for all consumers. If a proper study is made previous to the contract for the expansion, the deficiencies of the existing facilities will be apparent, and an intelligent decision can be made as to whether or not the extension is to be made.

Water service extensions frequently are made in a sporadic and haphazard fashion, resulting in a future distribution system containing too many under size pipe and "dead end" pipe lines. Both of these are a constant source of trouble, and finally result in expensive replacement costs to correct the lack of proper planning in the first place. A study should be made prior to making any extension, to determine how the proposed extension can be properly integrated into the present system. Such a study will provide pipe lines of adequate size for anticipated reasonable future growth of the area to be served, and will reduce to a minimum "dead end" pipe lines.

Pipe Sizes

The matter of selecting pipe lines of the proper size to meet the demands of the area being served by the extension is very important. Too frequently a municipality or water district will, through expediency, make extensions using small size pipe lines that are no more than adequate to supply the demands for water. Such a policy is very short sighted. It would be better policy to defer the installation of water service until such time as the area requesting the service is willing or able to install pipe lines of adequate size.

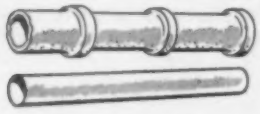
The demand for water service can be observed in any community where water line extensions are being made. It will be observed that as soon as a water line is installed along any street, that street will soon be completely built up while adjacent streets of equal development characteristics, but without water service, will not attract a single home. When a street is built up, the residents immediately demand, not only a good domestic water service, but fire protection service also.

Since water service extensions should provide for fire protection as well as for domestic service, the policy should be to limit the size of pipe to be used to the fire demand rate. The adoption of such a policy will result in pipe lines of minimum size of 6 inch diameter, since pipes of smaller diameter do not have the carrying capacity to support fire flows as required by the National Board of Fire Underwriters.

City officials, engineers, contractors will be interested in these...

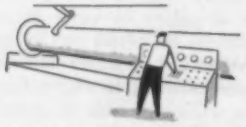
Facts About Steel Water Pipe

COMPARE THE COSTS... This drawing compares



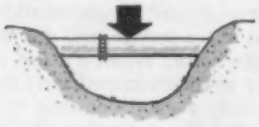
a single 40-ft length of steel pipe with 16-ft lengths of rigid-walled pipe of the same inside diameter. The steel pipe has thinner walls and a smaller outside diameter; weighs only about one-fifth as much per ft of length. Results: the steel pipe costs less to ship, to handle, and to lay. It requires a smaller ditch, fewer bell holes, fewer joints—only 132 per mile. Other pipe has more joints.

TESTED FOR STRENGTH... Every length of steel



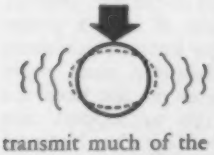
pipe is hydrostatically tested at the shop in accordance with AWWA specifications—usually to double the working pressure. What's more, steel pipe can withstand from 3 to 4 times the working pressure before bursting (we refer you to the chart on the opposite page). And steel pipe safely resists waterhammer, shock loadings and surge.

BEAM STRENGTH... Steel pipe has the structural



strength that is characteristic of tubular steel. It can span long washouts; is often handled in multiple lengths during installation. And steel pipe can stand up under the weight of extremely heavy cover.

ELASTICITY... Steel "gives" under stresses that



would cause more rigid materials to crack or break. Steel pipe can "absorb" traffic vibration as well as shock due to explosions and earth tremors. Its elasticity allows it to transmit much of the load to the surrounding earth. This is not true of rigid-walled pipe.

LEAKPROOF JOINTS... 100 pct bottle-tight joints

are a practical reality with steel pipe, whether mechanical couplings or welds are used. Water leakage is prevented; there's no contamination of the contents due to infiltration from without. These joints are quickly made, they're permanent, and they're strong.

CORROSION-RESISTANCE... Modern methods

of lining steel pipe with hot-spun coal-tar enamel make it immune to corrosion and incrustation. There is no known time limit to this protection. Many tar-enameled lines have been in service for upwards of fifty years. Coal-tar enamel provides the smoothest surface obtainable, assuring high flow coefficients year after year. Coatings and wrappings protect the pipe exterior from abrasion, moisture, acids and alkalis.

SHOP FABRICATED... Remember, too, that welded

steel pipe is fabricated in *permanent* shop buildings, using permanent production equipment and a permanent working force. Bad weather doesn't halt operations; freezing temperature can't effect product quality. There's no doubt of it: you get the maximum assurance of a top-notch product, delivered on time, when you use Bethlehem Steel Pipe.

WIDELY USED... Large-diameter steel pipe is the

growing choice of planners of municipal and industrial water systems. Some recent users of Bethlehem Steel Pipe are: New York City, New Orleans, Philadelphia, Savannah, Reading, Cincinnati, Atlanta, Omaha, Worcester, Colorado Springs and Boston. Further proof of the superior qualities of steel pipe is its use in thousands of miles of large-diameter gas and oil lines, as well as in high-pressure penstocks throughout the world.

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As this chart shows, steel pipe can withstand at least three times the calculated maximum allowable working pressure before bursting.

THEORETICAL INTERNAL PRESSURES OF STEEL PIPE

	1/4 in.			5/16 in.			3/8 in.			7/16 in.			1/2 in.		
IN-SIDE DIAM IN.	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	EST SHIP WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI
18	50	445	1390	62	555	1735	75	665	2080	88	775	2430	101	890	2780
20	55	400	1250	69	500	1560	83	600	1875	97	700	2180	111	800	2500
22	61	365	1135	76	465	1420	91	550	1700	107	640	1985	122	730	2270
24	67	335	1040	83	420	1300	100	505	1560	116	585	1820	133	665	2080
30	83	270	835	104	340	1040	125	405	1250	145	475	1455	166	535	1670
36	104	225	695	128	280	870	154	340	1040	179	395	1210	204	445	1390
42	116	195	595	144	240	745	173	285	890	202	335	1040	231	380	1190
48	132	170	520	165	210	650	198	250	780	231	290	910	264	330	1040
54				186	190	580	223	225	695	260	260	810	297	295	925
60				207	170	525	248	200	625	289	235	730	330	265	835
72							306	170	520	355	195	605	405	220	695
84							346	145	450	403	170	520	460	190	595
96	The recommended minimum wall thickness is approximately the pipe diameter divided by 165. Pipe having this diameter-thickness ratio, when backfilled and properly tamped, will withstand any depth of cover. For buried pipe, the recommended minimum thicknesses are shown immediately above heavy black line.									464	145	455	524	165	520
108													*605	150	465
120													*656	135	415

*Under certain conditions stiffeners may be required to reduce deflections.

$P = \frac{t \times T_s}{r}$ P = internal pressure, psi t = thickness, in. T_s = allowable unit stress = 60% x 27,000 (yield point) = 16,000 psi

r = radius of pipe, in. Based on use of ASTM A-283, Grade B Steel, 50,000 psi min. ultimate tensile strength

Free Booklets

Informative picture-story booklets, describing the installation of recent water-pipe projects are available to you without charge or obligation. Copies can be obtained from the nearest Bethlehem district sales office or by writing to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

- Ramapo Force Main, New Jersey; 25,000-ft line of 72-in. pipe. *Booklet 402.*
- Northwest Pumping Main, Reading, Pa.; 37,000-ft line of 30-in. and 36-in. pipe. *Booklet 408.*
- Lancaster, Pa., Water Main; 55,500-ft line of 42-in. pipe. *Booklet 431.*
- P.P.&L. Co. Flow Line, Hawley, Pa.; 8,500-ft line of 14-ft 8-in. pipe. *Booklet 432.*
- Industrial Water Main; Sparrows Point, Md.; 23,800-ft line of 96-in. pipe (please describe by name).

And for further information about Bethlehem Tar-Enameled Steel Pipe, kindly consult the nearest Bethlehem sales office as listed below.

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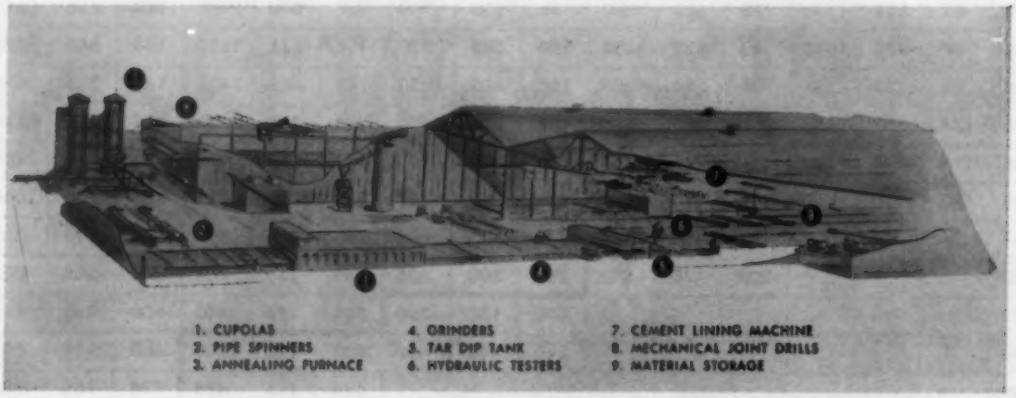

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The selection of materials for an extension should generally conform with those used in previous installations, providing they are adequate for the service. In making extensions to old systems however, one should not avoid adjusting standards to newer and better products.

Installing Pipe

The first thing to be considered in installing pipe lines is the trench excavation, for the quality of work obtained in installing the pipe will depend to a great extent upon the type of excavation made. The trench should be excavated to the necessary line and grade to accomodate the pipe in its designed position. The depth of trench should be such that the pipe has a minimum cover to prevent freezing during extremely low temperatures. Considering the temperature in the latitude of New York State, this would require a minimum cover of at least 3 ft 6 in. A minimum cover of 4 ft 6 in. is preferable. In northern New York State, experience might even dictate more cover.

The width of trench should be such as to permit ample working space for workmen placing the pipe and making the joints. This will require a minimum width of 18 inches for pipe six inches in diameter and smaller. For larger pipes, the most common rule for trench width is: the outside diameter of the pipe plus 12 inches.

Trench Bottoms

There are several types of trench bottom used in laying pipe. The following six methods have been studied and relative strength values determined for the various methods of installing pipe in the bottom of the trench.

A. Flat bottom trench, back fill not tamped.
B. Flat bottom trench, backfill tamped.
C. Pipe supported on blocks, backfill not tamped.
D. Pipe supported on blocks, backfill tamped.
E. Bottom of trench shaped to fit the bottom of the pipe for about 90 degrees, unevenness filled in with sand as required, backfill not tamped.
F. Bottom of trench shaped to fit the bottom of the pipe for about 90 degrees, unevenness filled in with sand as required, backfill tamped.

Method "C", pipe supported on blocks, backfill not tamped produces the greatest load that tends to crack the pipe. This method was commonly accepted 25 years ago, but today it is not recommended. Methods "E" or "F" are ideal, but are too expensive under present day high labor costs. As consulting engineers, we consider method "A"—flat bottom trench, backfill not tamped—to be satisfactory, and more apt to be accomplished in the field. Our designs are based on this method.

The trench should be excavated to a flat bottom to grade of sound earth, which will give the pipe good bearing for its full length. If the trench should be over excavated in depth, it should be built back to grade with satisfactory material, properly compacted. Bell holes should be formed at each joint, to permit room for properly constructing the joint. If rock or boulders are encountered in the excavation they should be removed so as to provide 6 inch clearance of the pipe. The extra depth excavation should be built to pipe grade with satisfactory material, properly compacted.

Placing The Pipe

After the trench has been properly excavated to receive the pipe, then the pipe should be lowered into the trench and installed piece by piece. Proper implements, tools and facilities for satisfactory, safe and convenient prosecution of the work should be at hand. All pipe, fittings, valves and hydrants should be carefully lowered into the trench piece by piece by means of power equipment, ropes, or other suitable tools or equipment, in such a manner as to prevent damage to pipe or pipe coatings. Under no circumstances should the pipe or accessories be dropped or dumped into the trench.

It is advisable, before lowering and while suspended, to inspect each pipe for defects and ring with a light hammer to detact cracks. Care should be observed to remove all foreign matter or dirt from the inside of the pipe and accessories before they are lowered into the trench, and to keep them clean during and after laying. Before laying pipe, all lumps, blisters and excess coal-tar coating shall be removed from the bell and spigot ends of each pipe; the pipe ends should then be wire-brushed and wiped until clean and dry, and kept clean until joints are made.

After placing a length of pipe in the trench, the yarning material for the joint shall be held around the bottom of the spigot so that it will enter the bell as the pipe is shoved into position.

The spigot should be centered into the bell, the pipe forced "home" and brought into true alignment; it should be secured there with earth carefully tamped under and on each side of it, excepting at the bell holes. Care shall be taken to prevent dirt from entering the joint space. At least four lengths of pipe should be in place ahead of each joint before it is poured. The pipe should always be laid with bell ends facing the direction of laying.

All pipe laying should be done in trench free from water. When pipe laying is not in progress, the open ends of pipe should be closed by approved means and no trench water should be permitted to enter the pipe.

Pipe Joints

The pipe joints may be of either lead, sulphur compound joints, or mechanical bolted joints. The method of making each will be briefly described:

For lead and sulphur compound joints a yarning material is required. The yarning material most frequently used is square braided hemp or jute, or rubber gaskets, which have recently become available. The material should be free from oil, greasy substances, or tar, and should be thoroughly sterilized before using. If the material is sterilized by the manufacturer, it should be so handled as not to be contaminated before being placed in the pipe joint.

Wherever a single strand of braided hemp or jute is required in jointing, the material should be cut to such length that the strands will reach entirely around the pipe with ends overlapping not less than 2 inches. Wherever more than a single strand is require, it shall be cut to sufficient length so that the ends meet without causing overlap. Those ends should meet on opposite sides of the pipe and not on the top or bottom. Successive strands of yarning material, as required, should be driven "home" separately. Each strand should be thoroughly packed and hammered into the joint with suitable yarning tools.

After yarning, sufficient space should be left in the bell to receive the joint material. For lead joints, on pipe 24, 30 and 36 inch pipe, a space not less than 2 1/4 inches in depth shall be left in the bell to receive the joint material. A space 3 inches deep is left for pipe larger than 36 inches. For sulphur compound joints, a space not less than 2 1/2 inches in depth shall be left in the bell for pipe whose nominal diameter is 24 inches or less, 2 3/4 inches in depth for 30 and 36 inch pipe, 3 1/2 inches for 48 inch pipe and 4 inches for 54 and 60 inch pipe.

For both lead and sulphur com-

pound joints, proper size joint runners should be used. The joint runner should fit snugly against the face of the bell, and the outside of the pipe. For lead it can be dammed with clay at the pouring gate to provide for filling the joint even with the top of the bell. For sulphur compound a suitable funnel shaped metal pouring gate, extending not less than 3 inches above the bell, should be adequately clayed to the joint runner, and filled with compound. The solidified compound in the pouring gate shall be cut off flush with the top of the bell, or broken off flush with the top of the joint. With either lead or sulphur compound each joint should be made with one continuous pour of metal or compound while the material is at the proper temperature.

Sulphur compound joints are not to be caulked. If the joint is defective, it shall be cutout and entirely remade. Lead joints should be caulked after cooling to the temperature of the pipe. They should be caulked by means of pneumatic tools, or by hand tools, by competent, experienced workmen until thoroughly compacted, making watertight joints without over-straining the bells.

Mechanical Joints

The mechanical joint is coming into wide use, due to the simplicity of making the joint and its watertightness. The joint has four parts: a flange cast integral with the socket or bell of the pipe; a rubber gasket fitting a recess in the socket; a gland, or follower ring, to compress the gasket; and the bolts and nuts for tightening the gland. The mechanical joint is simple to asemble. The gland, followed by the rubber gasket, is placed over the spigot end of the pipe, the pipe is inserted into the bell and shoved "home". The gasket is then pushed into position so that it is evenly seated in the socket. The gland is moved into position against the face of the gasket. Bolts are inserted and made finger-tight. Then, with an ordinary ratchet wrench, the bolts are tightened up. Where there is danger of the workmen pulling the bolts too tight, a tourque wrench can be used in lieu of the ratchet wrench.

A new O-Ring Type rubber joint has come on the market for cast iron pipe. Asbestos-cement pipe uses an O-Ring and slip joint coupling. Concrete pressure pipe uses a similar rubber joint and clamps to draw the joint tight.

Fittings & Valves

Pipe fittings should be installed in the same manner as the pipe, except that all tees, plugs, caps and bends exceeding 22 1/2 degrees should be securely anchored by concrete thrust backing. The backing should be placed between solid ground and the fitting to be anchored. The backing should be so placed that the pipe and fitting joints will be accessible for repair.

Valves for use in water pipe lines should be American Water Works Association standard. There are several manufacturers of this quality valve, and the make of valve should be left to the selection of the owner. From a maintenance standpoint, it is advisable to standardize on one or two, and not more than three makes in any municipality, instead of having several makes in the same system. Valves should be selected so that they all open by turning in the same direction.

Before valves are placed in the pipe line they should be thoroughly inspected to see that they are in first class working shape. Care should be observed to see that the valve is set true and plumb. The mechanics of making the joint connections to the pipe would be the same as described under pipe installation.

Each valve placed in an underground pipe line should have a cast iron valve box cover. The valve box should be firmly supported, and maintained centered and plumb over the wrench nut of the gate valve, with box cover flush with the surface of the finished pavement or surrounding ground level.

Backfilling

Backfilling of the pipe trench should be done in two operations. One being the procedure for backfilling at the pipe zone, and the other the procedure for backfilling above the pipe zone.

Backfill at the pipe zone should be done with select material, free from rock or boulders, to a depth of 6 inches over the top of the pipe for diameter of 10 inches or less, and not less than 6 inches above the center of the pipe for sizes 12 inches in diameter and over. The backfill material should be deposited in the trench simultaneously on both sides of the pipe for the full width of the trench.

Backfill above the pipe zone should be made with materials free from large stones, boulders, or similar materials, which may injure the pipe. If the excavated material is of suitable quality for backfill, the backfill may be done with power equipment. If it is important that there be no settlement, such as along highways where it is desired to resume vehicular traffic as soon as possible, or replace a permanent pavement, the backfill should be made in 6 inch layers with each layer thoroughly compacted, or if conditions are favorable the trench may be flooded. The backfill around the valve box should be made by hand and thoroughly tamped for the full depth of the exacavation.

Hydrants

Hydrants are usually spaced at about 500 ft. intervals, in accordance with the Fire Underwriters' Organization's recommendations. They should be located in a manner to provide complete accessibility, and in such a manner that the possibility of damage from vehicles or injury to pedestrians will be minimized. The hydrants should stand plumb. Those with one pumper nozzle should be set with the nozzle normal to the curb. Other type should be oriented as directed by the Fire Marshall of the community.

Each hydrant should be connected to the main with 6 inch cast iron branch controlled by an independent 6 inch gate valve.

Where hydrants are placed in impervious soil, a drainage pit, two feet in diameter and two feet deep should be excavated below the hydrant and filled compactly with coarse gravel or broken stone mixed with coarse sand, under and around the bowl of the hydrant and to a level of 6 inches above the waste opening. No hydrant drainage pit should be connected to a sewer.

The bowl of each hydrant should be well braced against unexcavated earth at the end of the trench with stone slabs or concrete backing, or it should be tied to the main with suitable rods or clamps.

The hydrant should be thoroughly cleaned and inspected before placing.

Inspection & Records

Water main extensions may be done either by "contract" or by the municipality's own personnel under "force account" work. If the work is done by contract, plans will be prepared for the work previous to construction, and usually, an inspector assigned to the work. In addition to seeing that the work is properly installed, the inspector would be required to keep an accurate record of the location of the pipe line, and all accessories, such as; fittings, valves, hydrants, service connections, etc. These data should be recorded in a "field book", with sufficient sketches, properly dimensioned so that anyone can use "field book" to relocate the individual items in the future.

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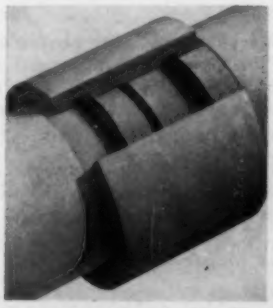

Sectional view of Ring-Tite Coupling is cut away to show how rings are compressed and locked in grooves to provide a *tight, lasting seal!*

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Installing 10" U. S. centrifugally cast iron pipe for a water distribution system

Section of 36" cast iron outfall sewer installed on concrete piers

CAST IRON PIPE FOR WATER SERVICE

The practice of using cast iron pipe for water service started in Europe around 1455 and around 1820 in this country. This practice has continued down through the years and it is still the most widely used type of pipe for water distribution systems. The most desirable combination of strength and long life has made and still makes the use of cast iron pipe the most economical in the long run. Our strategically located foundries are well equipped to furnish cast iron pipe and fittings in sizes starting at 2-inch for intakes, pump stations, filtration plants, supply, feeder and distribution mains.

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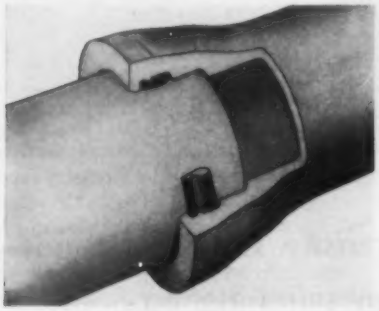
Cast iron pipe and fittings have a wide application in the sewerage field. They have three outstanding properties: 1. tight pressure type joints that prevent infiltration, 2. beam strength, compressive strength and bursting strength to withstand severe installation conditions, 3. long life and resultant low amortization charges that have been proven by years of satisfactory service.

Cast iron pipe and fittings in sizes 2-inch and up can be furnished for flow lines, pressure mains, siphons, stream crossings, outfalls, pumping stations and treatment plants.



U. S. TYTON JOINT PIPE

The newly developed TYTON JOINT® for U. S. cast iron pipe is simple, sturdy and tight. It has only one accessory—a circular rubber gasket which is modified bulb shape in cross section. TYTON JOINT is easily made up by placing the gasket in the socket and then lubricating the inside surface of the gasket. The entering spigot is pushed past the gasket until it makes contact with the base of the socket compressing the gasket between the outer surface of the spigot and the gasket seat of the socket. The result is a joint that will remain tight at pressures in excess of test pressures required by pipe specifications.

TYPES OF PIPE AVAILABLE

Our cast iron pipe centrifugally cast in metal molds is manufactured in accordance with American Standard Specifications A21.6 or Federal Specification WW-P-421a. Pit-cast pipe is made to conform to American Standard Specifications A21.2.

Fittings (bell-and-spigot) can be furnished in accordance with American Standard Specifications A21.10 for the short-body type 3-inch to 12-inch, also A.W.W.A. Specifications C100 3-inch to 60-inch for the long-body type.

Fittings (flanged) are made to conform to American Standard Specifications Class 125 (B16.1) and Class 250 (B16b) or long-body A.W.W.A. type.

Mechanical joint for cast iron pipe and fittings is made in accordance with American Standard Specifications A21.11. Pipe and fittings can be furnished with cement lining in accordance with American Standard Specifications A21.4 or manufacturer's standard.

Tyton Joint pipe, roll-on joint pipe, flexible joint pipe, flanged pipe and plain end pipe are made to standard or manufacturer's specifications, whichever are applicable.

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Distribution System Operation and Maintenance

by WALLACE T. MILLER
Research Engineer, Cast Iron Pipe Research Association in Chicago.

THE GENERAL SCOPE of the term water distribution system is very broad and would normally include distribution mains, valves, hydrants, service connections, meters, booster pumping stations, storage facilities, maintenance shops, etc. This article will cover the major items under this classification and particulary in respect to the more important considerations rather than a complete coverage.

MAINS

The specific locations of water mains are worthy of consideration in the early stages of planning. Many communities originally attempted to install water mains as near to the center of a street as possible, particularly in municipally owned utilities, and this no doubt developed from the thought of equalizing the cost of installing water service connections to property owners on each side of the street. As a result of a great preponderance of paved streets, it is very apparent that an effort should be made to keep water mains outside the limits of paved areas wherever possible. This general rule applies whether streets are already paved or are located within new subdivisions where paving will eventually be installed. The cost of removing and replacing of pavement can be a very considerable part of water main installation or maintenance cost and should be avoided wherever possible.

Selecting the Location, Size, and Joints

The selected location for the water main should prevent close proximity to any existing or proposed sanitary sewer or storm sewer. Many State Health Departments desire at least 10 ft horizontal spacing. Wherever it is deemed necessary to install water mains in the same trench with a sewer main, the water pipe should be laid on an undisturbed earth shelf on one side of the sewer trench and at such an elevation that the bottom of the water main is at least 18 inches above the top of the sewer main.

In many cases it can be determined that a two-main system can be installed on a street already paved at a cost which is no greater than the installation of a single main within the limits of the paving. In this case, a main would be located on each side of the existing street, one being sufficiently large to provide adequate flow for fire protection and other large flow requirements. The other, furnishing domestic service only, would be a main no smaller than 2-in. in diameter and connecting to larger size mains at each end of the block. The avoidance of pavement cutting and other work within paved areas, except at street intersections, will frequently provide sufficient funds to cover the cost of the second small main. Future maintenance costs may be considerably reduced. (See Fig. 1)

The matter of adequate sizing of mains is of prime importance prior to original installation and due consideration of future needs will avoid many maintenance problems at a later time. A minimum size of 6 inch diameter should be provided for any mains serving fire hydrants; long lines of this size, however, are likely to provide inadequate service. Any mains less than 6 inch diameter should be considered water service lines. Sizing of mains is a matter which is worthy of an extensive engineering study by a qualified engineering staff and should not be approached on a casual basis.

Selection of the type of joint most suitable and desirable for particular installation should also receive due consideration. Not many years ago most cast iron installations involved bell and spigot joints utilizing lead, sulphur compound or neat cement for joint materials.

For some years, the use of mechanical joint pipe has been gaining in popularity and now represents the joint which is most frequently used on new construction. This joint is very simple to install, has definite advantages over the bell and spigot joint and usually represents no increased cost. The mechanical joint is bottle tight, provides greater flexibility, reduces labor costs, eliminates separate jointing materials and can be readily assembled in a wet trench.

The most recent development in cast iron pipe is the Roll-on joint involving a compressed rubber gasket in a bell and spigot type of joint and

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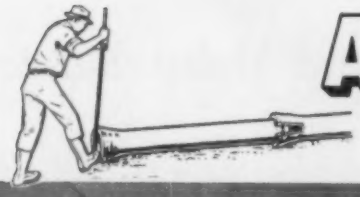
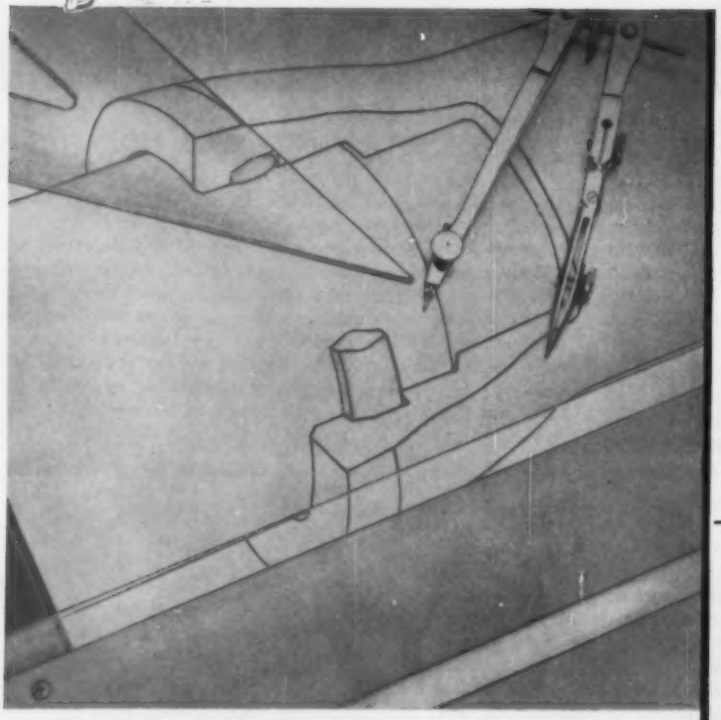


ALTITE JOINT By APCO



Four Operations
As Simple As Falling Off a Log—

Insert Rubber gasket in bell end of pipe — you can't put it in wrong — A child can do it.

Wipe on a small amount of special lubricant—This reduces friction.

Insert plain beveled end of pipe — there are no grooves, ridges or tips on gasket to interfere with smooth insertion.

Small amount of pressure required to force plain end to bottom of socket—Your simple, time saving joint is completed.

Efficient, Economical and Fool Proof—

The **ALTITE JOINT** has been subjected to a series of rigid tests much more severe than are encountered under the most extreme installation and service conditions in the field. Even under extreme conditions, this joint is so simple to install—you could hardly go wrong if you tried.

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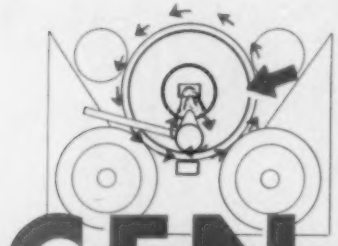
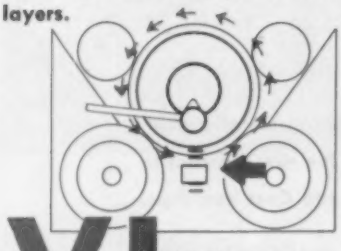
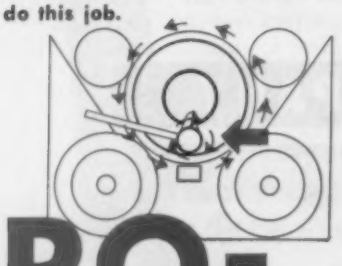


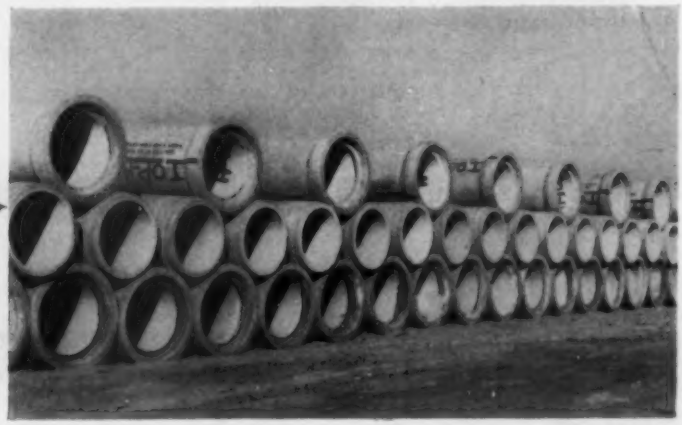
CEN- comes from CENtrifugally spinning the very dry "earth-moist" mixture, fed into the form by belt conveyor in uniform layers.



VI- comes from VIbration of the spinning form during the charging period. Specially designed vibrator-tampers on the underside of the form do this job.



RO- comes from ROlling the mixture under great pressure applied by a specially designed steel roller.



Recently, a large chemical company in Louisiana selected Cen-Vi-Ro Concrete Pressure Pipe to move fresh water into its new plant. Cen-Vi-Ro easily exceeded the hydrostatic and other test requirements, insuring the owners a permanent and maintenance-free installation. The close tolerances of Cen-Vi-Ro's precision-formed joints . . . measured in thousandths . . . combined with special O-ring type Rubber Gasket Seal assure perfect leak-proof connections under even the most adverse field conditions.

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in general this is the joint with the lowest cost installed. Flange joints are generally used for pumping station piping and other above ground installation. A ball and socket joint, usually called a submarine joint, is most appropriate for crossing rivers or other bodies of water.

Leak Repair

One of the most important maintenance operations in connection with water distribution systems involves repair of leaks. A very large percentage of leak repair work in the distribution systems, probably at least 90 per cent in most systems, is represented in service connection leaks. Most of the older service connections used lead, wrought iron or galvanized iron pipe and these are more susceptible to failure than most other parts of the system.

It is generally conceded that the replacement of an old service connection in its entirety through use of copper tubing or other satisfactory material, is much more economical than repairing an old service connection of unsatisfactory material. Where it is deemed advisable to repair an old service connection, several types of mechanical couplings are available for convenient repair.

Most leaks which do occur on mains are joint leaks. If sulphur compound has been used, the joint material may be cut out or burned out and the joint repoured. Lead joints can be recalked or clamps may be installed to provide a more permanent repair. It is somewhat common practice, where bell and spigot joints are used, to install joint clamps during the original installation on mains which may be located under railroads, superhighways or other vulnerable spots

For the relatively small number of breaks which occur in water distribution system mains, a great variety of mechanical clamps or sleeves are available for permanent repair. Prior to World War II it was difficult to get water works operators to think in terms of mechanical clamps as being anything other than a temporary repair and it was not uncommon for them to be used on a temporary basis for a quick repair and later removed. Operators have now been convinced that a mechanical repair clamp is a completely permanent repair item and mechanical fittings and pipe are common on new installations.

Mobile Radio for Leak Repair Operations

One of the most important tools in the repair of leakage on water distribution systems is to provide rapid and complete communications. All large water utilities, and many small utilities, have already provided communications through short wave radios or mobile telephone service. Invariably it is found that this type of service will pay for itself within a very short period of time through reduction of labor costs during periods of emergency. It also provides a considerable reduction in the time of disruption of service, which considerably improves public relations.

Main Flushing

One of the frequent sources of difficulty in many distribution systems is the existence of red water and the need for flushing at least a portion of the distribution system. Many systems find it desirable to provide at least a routine seasonal flushing. A complete flushing of an entire system should always provide for reversing the normal direction of flow and an increase in velocity which can usually be accomplished through closing certain valves on the system. Treatment of water can be very effective in avoiding the creation of red water problems and cement lining of cast iron mains will prevent the development of red water in a piping system.

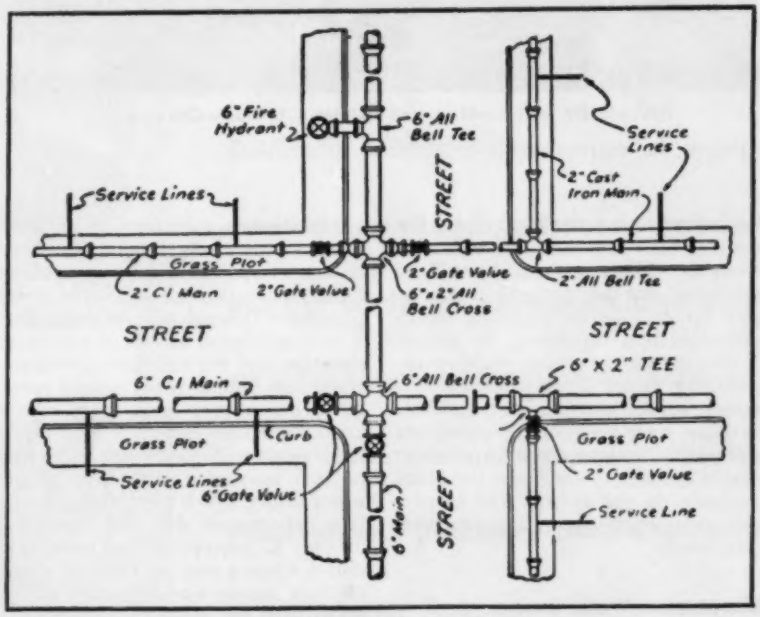

Fig. 1—DIAGRAM of two-main system

Disinfecting Mains

One item of extreme importance in operating procedures which is not always undertaken is the need for disinfecting new mains before placing these mains in service. Chlorine should be applied at the rate of not less than 50 ppm and should have at least a 24-hr contact period.

Holding of such a main out of service after complete flushing, until bacteriological analysis can be completed, is often inconvenient but should always be provided. Invariably, there seems to be some customer waiting immediate service and frequently this time element is shortened in order to convenience the customer.

It is not desirable that the time element be shortened, the bacteriological analysis should be undertaken and state health department regulations should be literally followed in each state. The AWWA has published a standard procedure for disinfection of water mains and this is available in reprint form.

Occasionally it is desirable to use chlorine in relatively concentrated dosage to eliminate the formation of slime growths in mains. This procedure can be very effective and usually requires a high velocity flushing following the disinfection.

Maintaining Capacity

The maintaining of adequate capacity may develop as a problem in many water systems and this situation has been extremely prevalent in

INSTALLING mains—42-in. roll-on-joint C.I. Pipe—Chicago, Ill.
Placing offset in 8-in. main

too many systems during the past few years of heavy demand and extensive droughts. Many articles have been published on the procedures necessary for completely analyzing distribution system capacities. A project of this nature invariably requires engineering talent for a complete hydraulic survey and it is not desirable to delay such needs until inadequate service is experienced. An effort should be made to anticipate increased demands on the system and to provide reinforcements in time to meet such needs.

Non-revenue Water losses

Of great importance in the operation of any water distribution system is the need to minimize losses through unaccounted-for or non-revenue water. Probably the best safeguard which can be undertaken to provide a high percentage of accounted-for water could generally be referred to as development of a good maintenance program. Water produced can become non-revenue water through inaccuracy of meter registration, leakage in the system, stolen water and from other causes.

Frequently this unaccounted-for water is extensive enough to warrant expending money for professional leak surveys which would cover all phases of the system. In the absence of undertaking a professional survey of this nature, simple leak surveys may be undertaken by any water department regardless of size. For example, there is a case on record of a municipal water district of some 500 customers where only one gallon of water was recorded on customer meters for each four gallons of water purchased through the master meter. This is an absurd as well as expensive situation and the exertion of nothing more than simple effort would result in saving a very large part of the unaccounted-for water.

More than 20 years ago the writer became associated with a municipal water utility which produced one million gallons per day and accounted for only 67 per cent of the water produced. Over a four year period a simple leak survey was diligently undertaken with the result that production of water remained at one million gallons per day, during a period of modest growth, and 87 per cent of all water produced was recorded on customer meters.

The procedure followed to increase accounted-for water by 20 per cent was very simple. An extensive meter maintenance program was undertaken. Repaired meters were required to meet a rigid test. Many very old meters were replaced with new meters.

A simple leak survey was undertaken which involved listening for leaks on every customers service, at the meter location and at the curb shut off. Listening devices were also used on every hydrant and every valve in the entire distribution system. During the course of the survey every curb shut off was operated and those failing to operate were promptly repaired or replaced. The entire increase in accounted-for water was the result of repairing leaks located in the distribution system and obtaining accurate registration of meters.

Safety

In conducting operation and maintenance work as well as in new construction, definite effort should be made to prosecute the work under the best standards of safety practices which are known. This is a responsibility of the manager of any water utility and a safety program should be in existence in every utility regardless of size. The AWWA has recently published a manual on safety practices related to the water works industry.

VALVES

One of our first concerns in respect to valves in a water distribution system relates to the location and extent of valve installations.

Number of Valves

The ideal installation might provide for four valves to be located at every water main intersection and, if blocks are unusually long, it may be desirable to install intermediate valves within a particular block. Most new main installations involve undeveloped areas or areas in the process of development as residential areas. Too frequently we think of present day need for valves and have a tendency to install an absolute minimum number. The same areas, when completely built-up, naturally present a greater need for valves and this should be borne in mind at the time of original installation. It would be difficult to find a water distribution system where a surplus of valves had been installed.

Industrial Connections

Where industrial plants or other large and important customers are connected with a distribution system, it is good practice to encourage the customer to provide two connections to the main and to locate a valve between the two points of connection In this way, it is possible to continue service to the customer regardless of the need to shut down a main in the particular block in which service is provided.

Loss of water service to an industry can result in a complete shut down of the plant and the loss of thousands of hours of labor. Even though such a shut down may occur very infrequently, the avoidance of complete loss of water service to industrial users is well worthy of consideration.

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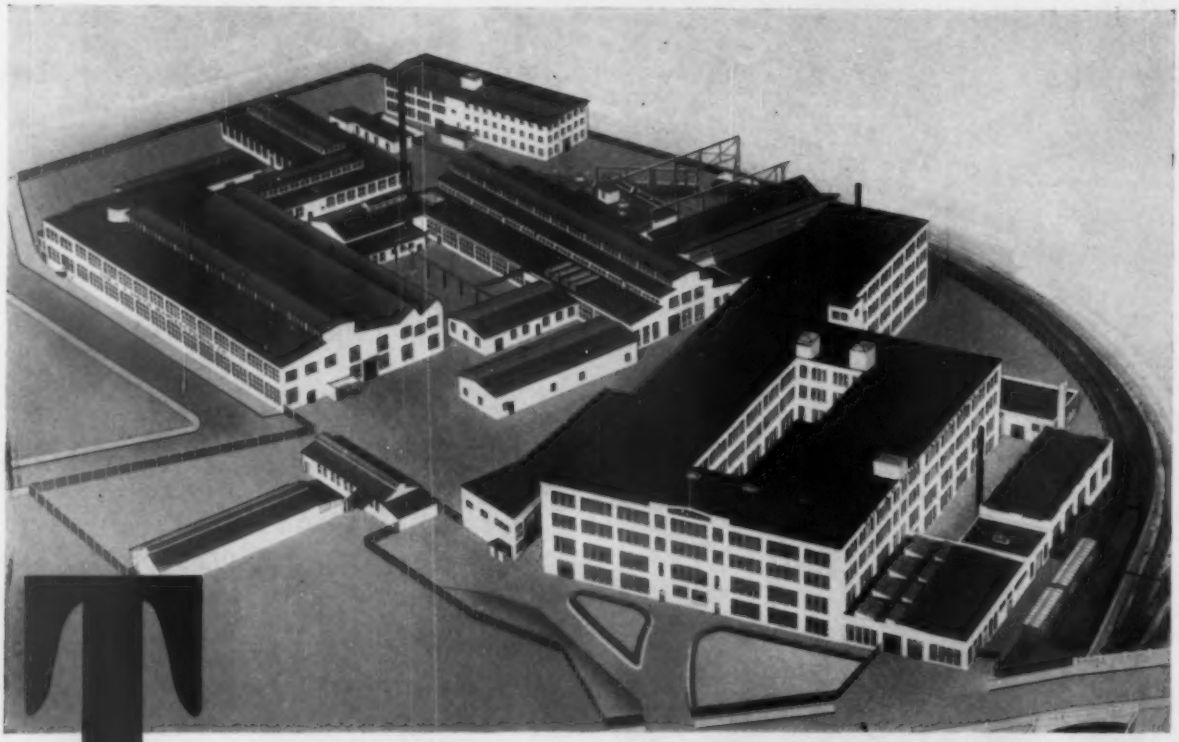
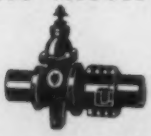
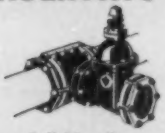


THE A. P. SMITH MANUFACTURING CO.

produces, FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types. GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service.  INSERTING VALVES sizes 4" thru 48" for inserting under pressure.  TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.

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Valve Operation

We hear a great deal as to the frequency of operation of valves. It is, of course, to be desired that each valve in the system be operated at least once a year but few small systems undertake a program of maintenance which will provide this. Some consideration should be given to the operation of valves, particularly important valves in the system.

Operators should be well trained to provide a reasonable time for closing and a definite avoidance of closing a valve too quickly. The number of turns required for complete opening and closing of every valve in the system should be known at the time of operation. Motorized valve operating equipment is becoming more common and represents an indispensable item of equipment in many departments. By-passes on large valves serve a very important function in connection with valve operation.

Packing Glands

Probably the greatest source of annoyance in connection with valve maintenance arises from difficulty with packing glands. Unless valves are located within valve chambers it is not convenient to tighten packing gland bolts or to replace faulty packing. Some assistance has been provided through equipment which permits some lubrication of the packing through the valve box. Valve chambers are desirable on large major valves where such are located within the area of rigid pavement.

Standardization of Valves

The matter of standardization of valves must be considered in any system in respect to the needs of that particular system. The same factors applied to valves will probably apply to meters, hydrants, and other items of material and equipment in any system. In ordering new parts for very old valves, it has been found desirable to purchase a complete set of internal replacement parts rather than procuring an individual item such as a stem, disc, etc. Use of a complete internal valve assembly will accomplish the most effective repair and will avoid difficulties which might be experienced in combining old and new operating parts.

A water works system should involve either right hand valves entirely or left hand valves entirely, but practically every system has a few valves which operate in what represents a reverse direction for that particular system. When that condition does exist, precautions should be taken to avoid assuming that the valve operates in the conventional direction. This may be accomplished in several ways. There are some systems where red paint is applied to the underside of the valve box cover to designate a particular valve as being unconventional in direction of operation. In other systems a similar precaution is undertaken through placing a piece of 2 x 4-in. timber in the valve box and the necessary removal of this calls attention to the reverse direction for operating that particular valve.

Valve Boxes and Records

Valve boxes should be maintained to provide accessibility to the operating nut at all times, even though this sometimes involves a considerable expense. A valve in the system is of no value whatsoever if it is not accessible for operation. Plugged valve boxes may frequently be cleared by flushing out with high pressure water through a small nozzle or by a blast of air from a compressor. In recent years we have experienced the repaving of many concrete highways through the application of about 2½-in. of blacktop on top of the old paving. This represents a problem in the adjustment of valve boxes, but a small unit is available for placing in the top of an existing valve box to adjust to the height of the new pavement.

Valve record cards are probably the most important item of records relating to the distribution system. There are many ways of providing reference measurements to determine location of valves and a standard system should be adopted in each department. Records of this nature should always be developed from the point of view of convenient field use and not on the basis of an office record which is not immediately available in the field.

HYDRANTS

Location

The matter of spacing of hydrants is important in a system and there is a wide variation in the spacing used. In residential areas it is desirable that hydrants be no farther apart than 600 ft. In any case, every building should be within 500 ft. of a hydrant. Business and industrial areas require closer hydrant spacing. Wherever possible, it is most desirable to locate hydrants at or near intersections so that they may conveniently serve along blocks in each direction.

If hydrants are placed between corners, an effort should be made to locate the hydrant opposite property boundary lines. They must be protected from damage by vehicles. Most customers object to having a hydrant located in front of their property and it has been found desirable to stake the location in advance, with a stake clearly marked "hydrant", so that any difficulty with customers can be worked out prior to placing the hydrant. Be sure to avoid future driveway locations. A standardization of threads must be established and steamer connections should be provided.

Valves should always be located on branch connections to hydrants and location on the branch near the point of connection to the main is more desirable than any other location.

Inspection

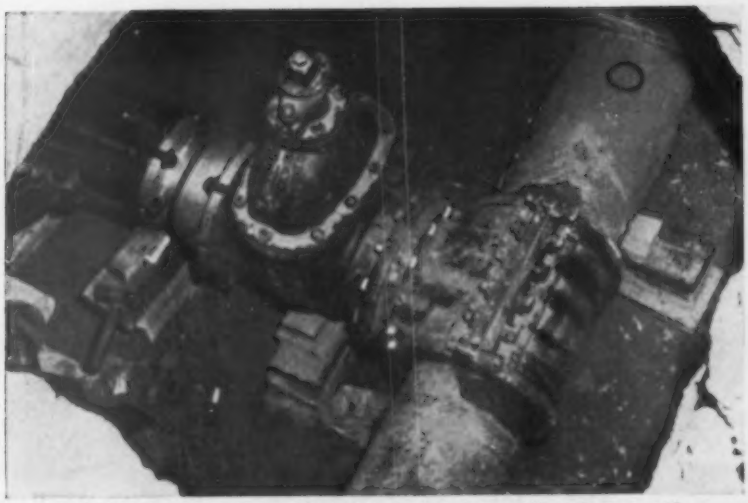
Hydrants should be inspected periodically to insure proper operation, adequate drainage and to provide necessary lubrication. Use of hydrants by persons other than department employees should be avoided due to possible damage through misuse, quick closing, etc. Where hydrants are used for sewer flushing, an auxiliary valve should be placed on the outlet and this valve operated rather than the hydrant valve, during the progress of such work. It has often been found practicable and desirable to furnish services of a department employee to operate hydrants rather than to permit operation by others.

Painting

Painting of hydrants should be standardized in any department and should be applied frequently enough to maintain a completely satisfactory and attractive appearance. In most water systems, hydrants are the only part of the system which are in evidence to the public and a neat appearance will provide public admiration. Many departments have eliminated chain connections to outlet caps and when these caps are made wrench tight, little disturbance or loss of caps may be expected.

It is generally desirable to indicate the flow capacity of a particular hydrant through marking in some manner. Flow tests should be undertaken to determine flow capacities and hydrants marked accordingly. Some departments prefer to indicate the size of the street main and mark this information on the hydrant rather than indicating the capacity. Any information which can be provided will be of use to the fire department and help to establish good relations.

Wherever hydrants may be taken out of service for a temporary period, or have not yet been provided with service during the construction period, a burlap bag should be placed



TIEING-IN 16-in. cement lined C.I. feeder main with 131 year old 10-in. pipe—Philadelphia, Pa.

over the hydrant or the hydrant marked in some way to indicate it is out of service. Hydrants should not be used for water required in private construction projects.

Hydrant record cards should be provided and all maintenance work undertaken on each particular hydrant should be noted on a continuing record. It has often been found desirable to have maps placed in fire houses to provide information on location of hydrants for assistance to fire department personnel.

SERVICES

Small service connections are generally made through installation of a fitting referred to as a corporation stop but it is difficult to establish the manner in which this name came into common usage. It is noted that plumbers in many areas of the country refer to water main piping as "corporation" pipe. Before the time when large private corporations were established, municipal governments were known as "the corporation". People who worked for the state, city, town or village on highway or other type of outside work, were generally referred to as "working for the corporation". The writer feels that this is the manner in which the designation of corporation stop came into common usage.

Sizing the Service

Determination of proper size of service connections for any particular customer should be given consideration at the time of application. There are definite disadvantages to installation of a service connection which is too large or too small for the particular type of service. The size of the service generally determines the size of the meter to be installed and a meter larger than required is likely to result in under registration on small flows.

In most areas it is common practice to install meters one size smaller than the size of the service connection. A service connection which is too small for the service desired will, of course, result in complaints of inadequate service. Some departments, as long as 20 years ago, were installing a minimum size service connection of 1-in. copper in order to provide completely adequate service many years later.

Selection of material should be given adequate consideration. Copper tubing is by far the most popular material for small service installations. In most cases, the corporation stop is inserted at an angle of 45° above horizontal with sufficient piping material available to provide for some movement of the service connection piping without creating a strain at the point of connection.

When the corporation stop is not conveniently available for shutting off to undertake repairs, excellent results may be obtained through use of dry ice for freezing. It is often found desirable to replace old service connections rather than to accomplish a repair, once a failure has occurred.

Curb shut offs should be maintained in proper operating conditions at all times and this will require periodic inspection and operation. Lids for curb boxes have a tendency to become damaged but repair lids are readily available and easy to install. A plugged curb box may frequently be cleared through use of blowing out with high pressure air or washing out with a jet stream.

Cost of Installation

In the majority of municipal operations, the cost of installation of a service connection is generally paid for by the customer and in some cases the department requires maintenance of the entire service connection at the expense of the customer. It is felt desirable that all work performance in maintenance of service connections, between the main and the curb shut off, be undertaken by department forces even though the cost of such maintenance may be charged to the customer.

Care should be exercised to install service connections at sufficient depth to prevent freezing. The thawing of frozen services is not particularly difficult but has considerable nuisance value, develops poor public relations and requires a continuous flow of water being maintained after thawing until all danger of freezing is over for the season.

There are a variety of opinions as to the advantages of installing service connections in advance of building needs and this has resulted from the extra expense required for installation after pavement has been completed. Pipe pushing and boring equipment has effectively reduced the amount of open trench installation. Too frequently service connections installed many years in advance of building needs have resulted in the stub service being at the wrong location or of inadequate size. The particular factors related to each individual community would be of great importance in establishing a policy. The two main systems eliminate the need for such considerations.

As is true of all other distribution system appurtenances, service record cards are of great importance. They should effectively designate the particular location of the point of tap and curb shut off and should provide a convenient method of satisfactory measurement to locate the curb box rapidly. The record should also include installation details and any

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Mechanical Joint Tapping Valves and Sleeves

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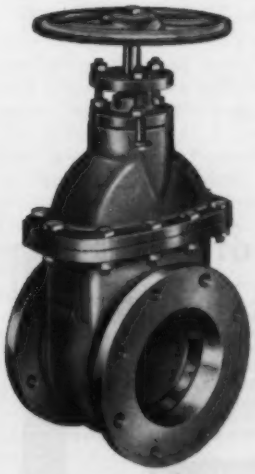

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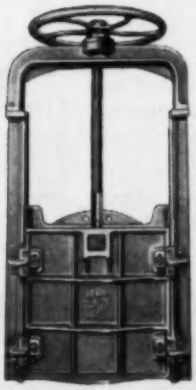

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Right: Standard Model Hydrant

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M & H A.W.W.A. Gate Valves are furnished double disc parallel seat, or solid wedge, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2" to 36". Low Pressure and High Pressure Valves and Square Bottom Valves are an established part of the M & H line.

M & H Compression Type Hydrants conform to latest specifications of the American Water Works Association. They are available either in standard, flush type or traffic models. Hydrants with 5¼" and 6¼" valve opening are listed and approved by Underwriters Laboratories of Chicago and Associated Factory Mutuals of Boston and A.W.W.A. Hydrants with 4¼" and 4½" valve opening are A.W.W.A. approved only.

Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

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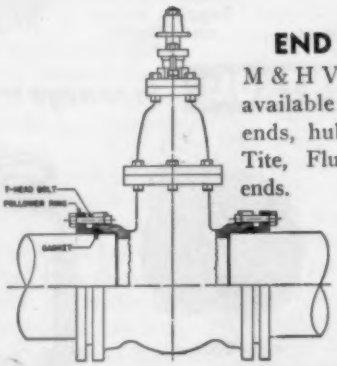
M & H Flap Valves and Shear Gates are iron body, bronze mounted, used in Filtration and Sewage Disposal Plants.

Hydraulic Gate Valve

Low Pressure Gate Valve Non-Rising Stem

END CONNECTIONS

M & H Valves and Hydrants are available with Mechanical Joint ends, hub ends, flanged, Ring-Tite, Fluid-Tite and Universal ends.



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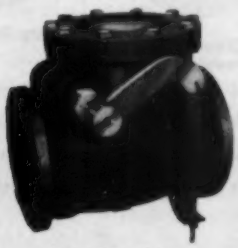
M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

Rising Stem Gate Valve



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Indicator Post

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FLAP VALVES	S & S FITTINGS	FLANGE AND FLARE FITTINGS
CUTTING-IN VALVES & SLEEVES		CUTTING-IN TEES

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maintenance work performed on the service connection.

METERS

Nothing is of more importance to good revenue production than an adequate meter maintenance program. All small meters should be brought into the shop, cleaned, repaired, tested and properly adjusted on a periodic schedule. Large meters require similar work in the field. The frequency of inspection and maintenance varies on small meters from five to ten year periods but should logically be based on the volume of water passing through the meter rather than time.

Many large utilities remove residential meters upon registration of one hundred thousand cubic feet. Average sized families would be expected to use this amount in approximately ten years. Privately owned utilities are generally regulated through state utility commissions and definite schedules for meter maintenance are established.

Meters should be located in such a manner as to provide convenient access for reading by meter readers. Any poor settings or locations should be corrected at the earliest opportunity.

It is frequently found that municipal utilities require purchase of a meter by the customer even though control rests with the utility. Since the meter represents the cash register of the water utility, it is desirable that both ownership and control be vested in the water department. One of the great advantages is represented by the fact that ownership by the utility avoids the necessity of maintaining any particular meter at the same location at all times.

The meter maintenance shop should be adequately equipped to provide the complete requirements of testing and repairing. An excellent article on "Equipment and Layout of Meter Maintenance Shop" appeared in the June 1954 Journal of AWWA.

STORAGE

Whether storage of water in the system is maintained as ground storage in open reservoirs or as elevated storage in tanks and standpipes, it is important that good housekeeping be maintained to set a pattern for the community. These facilities are in the same classification as city buildings and all other public property and should always be outstanding in appearance. Invariably good housekeeping of this sort will also provide more effective use for longer life.

There is a wide variation of opinion in respect to use of supply or storage reservoir property for recreational purposes. It is necessary to guard might better be avoided unless adequate policing can be provided, rather than to permit a nuisance and possible source of pollution to develop.

DEMANDS

During the past few years of frequent droughts in many areas of the country, more than one thousand water systems throughout the U.S. have found it impossible to meet total demands on their systems at some time during the year. The developement of our high standard of living has resulted in continuing increased use of water by all consumers and the population of the country is growing by leaps and bounds.

Industrial demands have grown steadily and it is anticipated that they may more than double in the next 20 years. Air conditioning is developing a tremendous load on some water systems in commercial and industrial areas. Lawn sprinkling has frequently developed peak demands far in excess of adequate fire flow requirements in residential areas. Fire flow requirements were formerly used to determine peak capacity needs in many water systems but industrial and sprinkling loads may be expected to exceed these demands in many areas.

The operator of a water distribution system should be entirely familiar with what is taking place on the system during periods of peak use. Pressure tests under peak loads are of tremendous help in determining adequacy of service or need for reinforcement of any particular part of the system.

It is relatively simple to obtain hydrant pressures throughout the system during these periods. Pitot and fire flow tests must be undertaken periodically to develop information for necessary hydraulic study at frequent intervals. Major hydraulic grade study or similar investigation of conditions should be undertaken at regular intervals to provide long range planning on any system. A considerable amount of information may be obtained during the peak season by water department forces which will provide valuable information for both short range and long range planning.

CUSTOMER SERVICE

The legal obligations related to water service on the part of a utility are generally within the limits of public property. The exception might be

MOBILE radio phone aids communications—Cape Cod, Mass

the meter, which may be located in the customers premises. However, the utility may well consider a moral obligation to extend service, but not necessarily responsibility or repairs, to include matters related to the use of water within the premises. This philosophy of service is rather extensively performed in the electric, gas and other utility fields.

No matter how well a water distribution system may be operated or maintained the existance of unsatisfactory conditions within the customers premises may result in unwarranted criticism of the utility.

One of the most extensive problems of customer service in a water utility is the handling of complaints. These represent a tremendous variety but in general most complaints, regardless of the foundation, occur at a time when the consumer has just received or is proceeding with payment of a bill. Complaints should not be treated lightly, since the average customer may have some reason for complaining only once in 10 years or more time and yet this will likely be his only contact with the department during that period of time.

In order to perform the function of the department and maintain good public relations, it is necessary that adequate service be rendered to the customer. Every complaint is worthy of complete investigation and when complete investigation is undertaken, there is invariably a reasonable answer as to the cause of the condition which resulted in the complaint.

Complaint Handling

The most frequent complaint from customers relates to what may be classified as an unusually large or at least an increased bill for water. In one particular municipal utility, an extreme effort was undertaken to definitely prove the reason for the increase in consumption which resulted

in the complaint. In practically every investigation, a satisfactory answer was determined and it was rare to find a case where this was not true.

The procedure which was used provided for sending an inspector to the property with complete information as to meter readings, dates and consumption recorded for several periods prior to the current period under investigation. An additional reading at the time of investigation, which probably involved a relatively short period following the previous reading, was first obtained and all usage was converted into average daily requirements for each period in gallons or cubic feet per day. These units can easily be extended for 90-day periods for convenient comparison when discussing quarterly consumption with the customer.

Actual tests were made to determine exact requirements for water in the operation of each water closet at the property. A record was made of any appliances requiring water. The number of persons served at the property was of great importance and was used in establishing per capita uses for comparison to average demands by other customers. Every complaint resulted in a complete letter report to the customer from the manager or a conference between the customer and manager to discuss all of the factors involved.

It was generally found that the majority of complaints relating to increased billing resulted from leakage within the customer's property. It was determined that alertness on the part of the meter readers could determine this prior to the actual billing time and generally resulted in more prompt repair of leaks. Meter readers were trained to make comparisons with consumption during previous periods at the time of meter reading. If increase consumption were noted, they immediately listened on the service at the meter to determine whether water was running continuously. Wherever possible, the matter was discussed to some extent with the customer at that time. If the matter was not resolved immediately, the meter slip was designated by code number as requiring additional investigation by an inspector. In this way the majority of increased bills was investigated and resolved from one to three weeks prior to the actual rendering of the bill.

A continuing program with conscientious effort can result in tremendous improvements in public relations as well as considerable savings through reducing wastage of water.

CAUSES of leaks. Assortment of service pipes—Glen Ellyn, Ill.

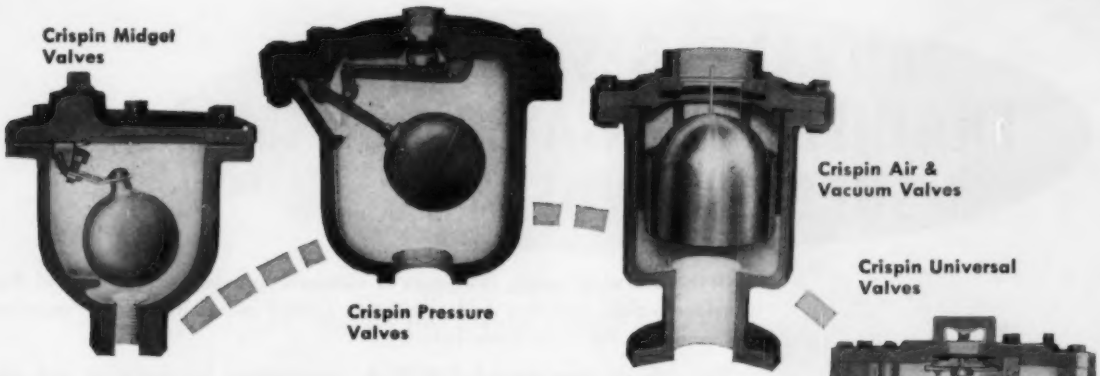
Meter Reading

Wherever access for meter readings cannot be obtained, it is generally desirable to leave a post card to provide for convenient reading by the customer. Where this has not been found satisfactory, arrange to leave some notification that an effort has been made to read the meter. Efforts of this nature are always a safeguard against complaints which may result at some future time since many customers became very irritated when their regular billing period has been skipped, or estimated bills are established.

Capable and alert meter readers can be a most valuable asset. Too often their work has been limited to nothing more than a simple recording of a meter reading. Most meter readers are capable of using good judgment and should be encouraged to observe and report changes in rate of consumption, as well as any unusual or undesirable conditions. Many such conditions occur frequently and may be conveniently reported by code number. Any follow-up required may be undertaken by other employees. In one department, the following code was attached to each meter readers book to permit ease in reporting that he was aware of specific factors at the time of reading, or conditions which required some further effort.

1. Meter not registering
2. Was a leak—has been repaired
3. Water closet leaking
4. Bad faucet leak
5. Meter coupling leaking
6. Meter stuffing box leaking
7. Meter registering slowly—indicating leak
8. Meter registering slowly—water cooled equipment
9. Consumption high—reading correct
10. Consumption low—reading correct
11. Meter not accessible
12. Premises vacant—left card
13. Quarantined
14. Glass broken
15. Register broken
16. Frozen
17. Meter set backwards
18. Hear water running—meter not registering
19. Meter seal broken
20. Meter working O. K.

When attempting to provide an efficient operation of a water distribution system, nothing pays greater dividends than the exertion of a sincere, conscientious effort and the application of good common sense on the part of the manager.



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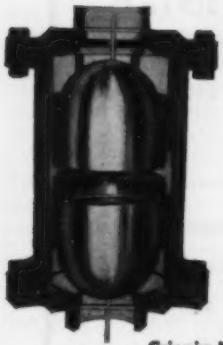

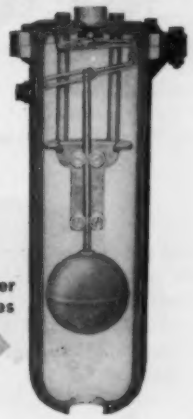

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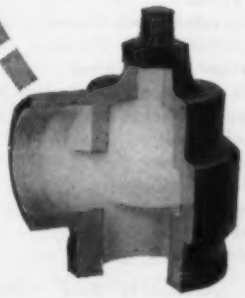

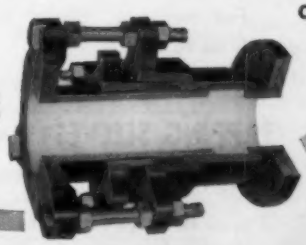

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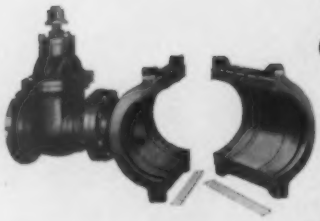

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Distribution System Leakage

by E. E. BOLLS, Jr.

Principal Engineer, Black & Veatch, Engineers, Kansas City, Mo.

IN MANY WATERWORKS systems, the feeling prevails that leakage, like poverty, death, or taxes, is always with us. Like many statements containing a modicum of truth, this one can lead to wasteful operations if taken literally.

For the purposes of this paper, leakage is defined as the difference between the quantity of water discharged into the system and the summation of the quantities measured by customer meters. It is true that a number of cities are not 100 percent metered and some cities operate under flat-rate schedules and have no meters. In such cities the reduction of leakage is a "hit-or-miss" proposition with a limited chance of success.

Par for the Course

In every water system there are numerous leaks that could be eliminated by a concentrated and continuing program of leak detection and repair. However, for each system there is a point of diminishing return on such a program and management, in each system, should determine the amount of leakage that will be tolerated. It can be stated safely that the vast majority of water systems could afford to expand their leakage control programs many times without reaching the point of diminishing return.

A rough yardstick to measure the efficiency of leakage control programs is provided by statistics from other cities. In June 1953, the *AWWA Journal* presented the results of a survey of more than 900 water utilities serving populations of at least 10,000. Complete or practically complete answers were returned by 416 cities.

The answers to the question of percentage of production sold varied widely, but gave good indication of the percentage of unaccounted for water. The raw information is somewhat misleading, as a number of the cities were not fully metered or did not record free water service. Therefore, the quoted percentage of production sold indicates more unaccounted-for water than is actual in such cases.

The median figure for all cities reporting was 84 percent of production sold. Thus, the median of unaccounted-for water is indicated to be less than 16 percent.

Louisiana cities reporting included:

1. Baton Rouge, 100 percent metered, 12 percent unaccounted-for.
2. East Jefferson, 100 percent metered, 20 percent unaccounted-for.
3. New Orleans, 100 percent metered, 45 percent unaccounted-for.

The New Orleans figure includes free water and a free water allowance for sewerage purposes. After correction for these items, the New Orleans system shows 35 percent unaccounted-for.

To supplement the results of the AWWA survey, a group of typical cities served by Black & Veatch in recent years is included in Table 1. The indicated median unaccounted for is 19.6 percent. The best showing in this group is by the Kansas City Suburban Company, which serves approximately 80,000 people. The low percentage unaccounted-for (9.1) is due in part to the age of the system, as most of the mains and services have been installed since 1940. It is probable that Cincinnati and Milwaukee are more representative of the older cities having excellent leakage control programs. The experience of these two cities shows that unaccounted-for water can be economically limited to 10 to 15 percent.

TABLE 1

Unaccounted-For Water in Selected Cities

City	Year of Report	Per Cent Unaccounted-For
1. Atlantic, Iowa	1954	21.7
2. Carthage, Mo.	1954	25.3
3. Chillicothe, Mo.	1948	17.0
4. Cincinnati, Ohio	1954	15.0
5. Fargo, N. Dak.	1953	22.9
6. Paragould, Ark.	1949	15.9
7. Neosho, Mo.	1956	48.0
8. San Antonio, Tex.	1954	19.4
9. Kansas City Suburban	1954	9.1
10. Kansas City, Mo.	1955	19.9
11. Natchez, Miss.	1956	19.9
12. Milwaukee, Wis.	1954	10.1

Irreducible Minimum

Unaccounted-for water results from leaks in the distribution system and under-registration of customer meters. Therefore, it is desirable to evaluate the probable meter loss in each system in order to establish a program of meter maintenance and leak repair.

An interesting article was contained in the *AWWA Journal*, Vol. 39, (1947), concerning the reduction in meter accuracy compared to length of time in service. This paper, by G. L. Williams of the California Water Service Company, presents a scientific approach to the determination of the optimum period for routine testing and maintenance of meters.

The studies for this paper found that the average meter accuracy declined very slightly for the first seven years of service. In subsequent years, the reduction in average meter accuracy was much greater, as shown in Table 2. From these studies and by a comparison of revenue lost to

cost of meter repairs, it was determined that the optimum period for meter reconditioning was about nine years. The optimum period would, of course, vary with each city, depending on water rates, quality of water, and cost of meter repair program.

In addition to the loss in accuracy resulting from age in service, even new meters will seldom register extremely small flows caused by drips from household fixtures. Therefore, it is estimated that customer meter loss will average 3 percent even with a meter repair program having a 9-year cycle.

In many cities, meters are allowed to remain in service until they stop. In these cities it is proable that the percentage lost through customer meters is extremely high.

A further measure of the "irreducible minimum" leakage can be made by an analysis of the miles of distribution mains in service. The previously mentioned AWWA survey showed that Baton Rouge had the equivalent of 155 miles of 8-inch pipe in service and East Jefferson had the equivalent of 116 miles of 8-inch mains. Using the allowable leakage formula contained in the AWWA pipe laying specifications, the theoretical initial distribution system leakage would be approximately 0.5 percent of production for Baton Rouge and 0.7 percent for East Jefferson.

Because these limits of leakage are for new construction and include no allowance for leaks at corporation cocks and service lines, the "irreducible minimum" loss from under- registration of meters and small leaks in the distribution system is about 5 percent.

Results of Leakage Control

It is apparent that most water systems reduce the unaccounted-for water to a range of 10 to 15 percent of production. However, as a result of low water rates and a past history of abundant sources of supply, many systems have made no concentrated and continuing efforts to achieve such a degree of control of leakage.

For the past decade, cities all over the nation have experienced (a) accelerated demands for water, (b) rising costs of construction and operation, and (c) less attractive sources of supplementary supply. As a result of this sequence of events, the water industry cannot continue to tolerate wasteful operations.

To evaluate the possible results of a leakage control program, consider a city having an average daily water production of 10 mg and assume the unaccounted-for water amounts to 25 percent of production. It is also assumed that 6 percent results from under-registration of meters and 19 percent is caused by system leakage.

TABLE 2

Effect of length of Service on Meter Accuracy

Length of Service, years	Average Meter Accuracy, %
7	99.5
8	99.0
9	98.0
10	96.0
11	93.0

Following a program of meter maintenance, leak survey, and leak repair, it is assumed that the meter loss is reduced to 3 percent and system leakage reduced to 12 percent for a total unaccounted-for of 15 percent. Using the average cost of chemicals and power for pumping as experienced at New Orleans and Shreveport, the following would be obtained:

Annual saving in power and chemical cost (365 x 0.7 mgd x $20 per mg)	= $ 5,110
Annual increase in metered sales (365 x 0.3 mgd x $200 per mg)	= $21,900
Saving in plant investment (0.7 mg x $250,000 per mg)	=$175,000
Equivalent annual saving ($175,000 x 0.04)	= $ 7,000
Total annual saving in reduction of unaccounted-for water from 25 to 15 percent	= $34,010

Establishing the Program

The first step in establishing a leakage control program is an accurate and realistic determination of unaccounted-for water. This should be based of the difference between production and metered consumption, with no estimates included for unmetered services, water used for street flushing, fire fighting, or water used for flushing of sanitary sewers. Meters should be provided on all services, including various locations allocated for filling street cleaning equipment, and these meters on free services should be read along with the other customer meters.

The Venturi or other type of master meters on the source of supply should be checked at least once each five years. A manometer check between the leads of Venturi or orifice meters will provide a check of the indicating and recording mechanism. A pitometer should be used to check propellertype meters.

After the master meters are checked, a period of one to two years of record is required to obtain an accurate determination of unaccounted-for water. This situation is a result of staggered billing and makes it necessary to average the percentages of a number of billing periods in order to obtain a realistic answer.

If the unaccounted-for water is 15 percent or less, the leakage control program is considered to be adequate but should be continued to limit leakage in future years to the 15 percent level.

If the unaccounted-for water exceeds 15 percent, the annual cost of that quantity above 15 percent may be computed as previously described, but using costs of chemicals, power and plant investment that are applicable to the individual system. It would appear reasonable to include a sum equal to one-half the indicated saving in the annual budget plus the previous year's budget figure for meter maintenance and leak detection and repair. It is suggested that this sum be separated into meter maintenance and leak detection and repair. The allocation to meter maintenance should be adequate to establish a 7- to 9-year cycle of testing and repair. The balance of the fund would be allocated to the detection and repair of leaks.

Immediate results should not be anticipated. The unaccounted-for water should be evaluated each year and the budget figure adjusted accordingly.

Locating Leaks With System Personnel

If a system map showing elevations at each fire hydrant is not available, the preparation of such a map should be the first item of work. The map should be drawn in ink on linen so that numbers of prints can be made. The elevations should be accurate to the nearest 0.5 foot.

After the map is completed, a program of hydrant pressure tests should be initiated. For best results, these pressure test should be made between 9:00 PM and 5:00 AM in winter months. The hydrants should not be flushed, as the resulting surges would influence the pressure readings. The work done each night should be carefully planned to cover as large an area, approximately square in shape, as possible. The pressure at each hy-

drant should be converted to hydraulic gradient and plotted on the map with different colors representing pressures measured on the same night.

Hydraulic gradient contours may then be drawn. The slopes of these contours are very helpful in locating major leaks. As a secondary benefit, these contours will indicate valves that are closed in the system. To obtain accurate results, the pressure gages should be checked at regular intervals and pumping heads should be maintained at a uniform level during the tests.

If the hydraulic contours indicate considerable flow in a particular main, the location should be spot checked to determine whether the indication is a leak or a heavy nightime load. If a leak is indicated, inspection of adjacent sewers will sometimes aid in spotting the location. Audiophones or other type leak detectors are also valuable once the leak is isolated within one or two blocks.

The foregoing cannot be expected to locate very small leaks. However, the general experience, in cities having 25 percent or higher unaccounted-for water, is that there are a number of large leaks. A city in Mississippi lists more than 1 mgd for a year through a break in a 6-inch pipe. The 6-inch pipe broke beneath a watercourse at a location less than 100 feet from its connection with a 24-inch main. This leak was discovered when extreme low water in the stream allowed turbulence to reach the surface. Pressure tests would have found this leak quite easily.

Leakage Surveys

A number of cities supplement their leakage control programs at regular intervals by employing specialists to perform leakage surveys. These surveys are based on a series of measurements with pitometers to determine the amount of water entering the system and the distribution of flow throughout the system. Such a survey would have the following functions:

1. Provide an independent check on the accuracy of master meters.

2. Check large industrial meters for accuracy by independent flow measurement.

3. Measure the distribution of the night rate of flow, almost block by block, so the location, as well as the amount of leakage, can be determined. Whenever these tests show abnormal flows, the leaks can be located by audiophones or similar equipment.

In conclusion, the cheapest source of supplementary supply is available from the reduction of leakage in the system. The most painless source of addition revenue is a meter maintenance program geared to limit customer meter loss to about 3 percent.

If the system's unaccounted-for-water exceeds 15 percent, leakage control measures should be started immediately.

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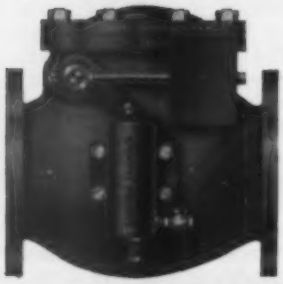

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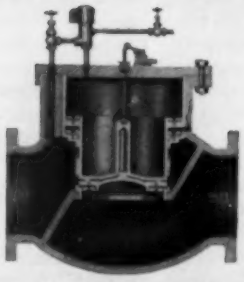

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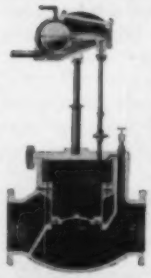

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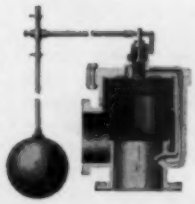

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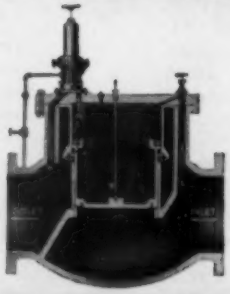

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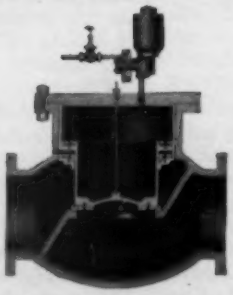

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by J. O. JACKSON

Vice-President in charge-of engineering and research, Pittsburgh-Des Moines Steel Co.

THE SERVICE LIFE and economical maintenance of steel water tanks depends upon thorough regular inspection and upon prompt and thorough repair and repainting as necessary. Aside from possible damage by floods, storms, or earthquake, the life of a steel tank is limited only by the damage due to corrosion of the tank plates and the supporting tower, if any.

The American Water Works Association's Specification D102, "Tentative Recommended Practice for Painting and Repainting Elevated Steel Water Storage Tanks, Standpipes, and Reservoirs," was prepared by a joint committee representing the American Water Works Association, the New England Water Works Association, and the American Welding Society. It is recommended as a guide to the owner of the tank, as to inspection, repair, repainting, and attendant contractual arrangements. Repair and repainting are such specialized and somewhat hazardous undertakings, particularly for elevated tanks, that they are seldom done by regular maintenance personnel. Instead, these functions usually are performed by contractors who are experienced in this work.

Inspection and Report

All tanks should be thoroughly inspected inside and outside at least once each year, preferably in the spring, to determine the extent of pitting or of paint failure by blistering, peeling, rusting, or abrasion (as by ice). The outside of a tank and its supports should be inspected for possible structural damage after every serious storm, flood, or earthquake. If the regular maintenance inspection is made in the springtime, the repairs and repainting, if needed, may be contracted for in time to have the work done under favorable summer conditions. The inspection should be done by the owner's maintenance superintendent, his engineer, or by any other competent and experienced in recognizing conditions which are or may become serious. Consulting structural engineers and many testing laboratories offer inspection services. Tank manufacturers usually offer such service for tanks of their manufacture.

The tank should be completely drained for the inspection. The interior surfaces should be washed down with a fire hose, to remove the slime from the walls. All dirt should be cleaned out from the bottom. Suitable rigging, to enable the inspector to check all parts of the structure, is essential. The detailed inspection report[1] should include an evaluation of the condition and recommended repair and/or repainting of the following: foundation(s), riser pier, anchor bolts and nuts, column bases, columns, sway rods, tower alignment and general condition, riser, frost casing (if any), ladders, balcony, struts, tank bottom, walls, roof, overflow, level indicator, heater (if any), valves, etc. Extreme care should be exercised during the inspection. Interior ladders and spider rods are usually the first items to deteriorate to unsafe conditions.

The report on the condition of the paint, or other protective coating, should include a description of the type of failure, if any, such as blistering, peeling, flaking, alligatoring, chalking, rusting, and the extent thereof in per cent and degree.

The report should include an estimate of the useful life remaining in the tank. The extent and depth of pitting is important: whether localized in spots which can be repaired by welding, or whether the pitting is general, requiring new sheets or structural members. If steel is required, the amount and location in the structure should be stated.

Action on Report

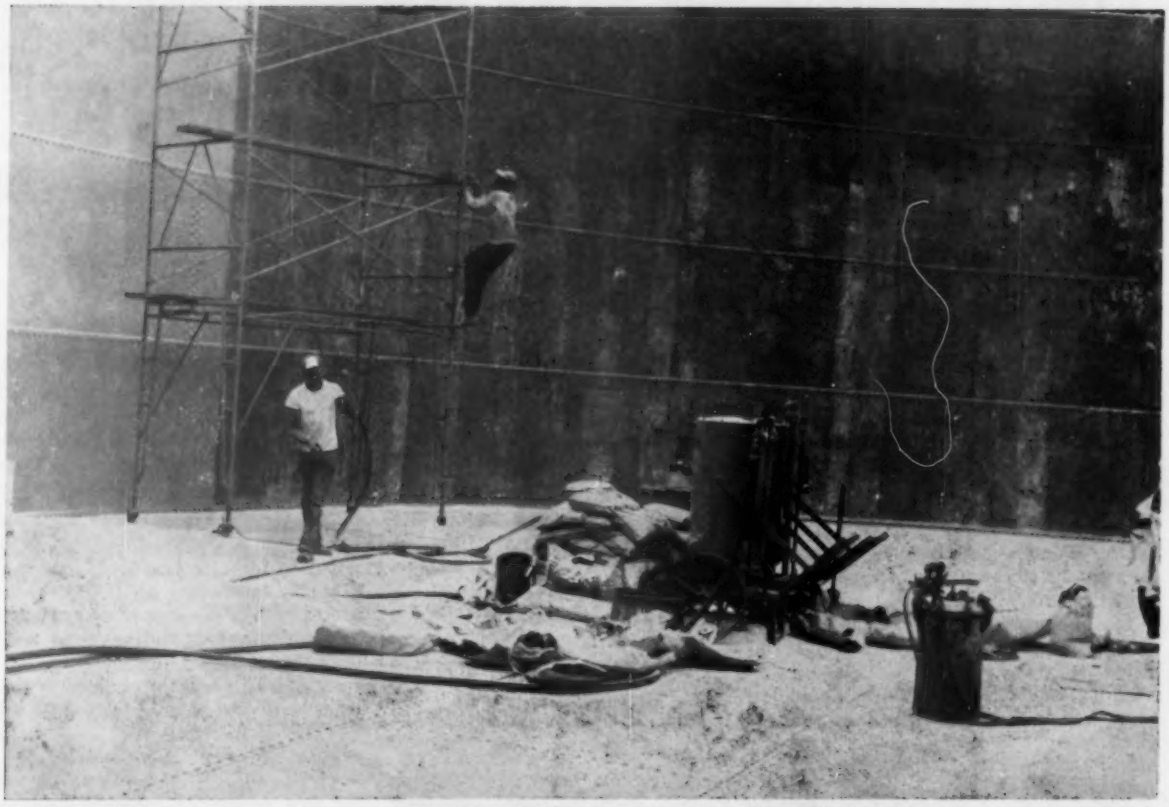
The report should be held confidential and should be made only to the persons who have ordered the inspection. Having received the report the person responsible for the maintenance of the tank will probably discuss the required repairs with the inspector and then plan the work accordingly. If the repairs consist only of things the owner can take care of with his own maintenance force, orders should be issued to have the work done and the report should be noted to indicate that each item was properly taken care of. If the repairs are extensive the owner may wish to advertise for bids and have the work done by some competent organization. It is of great importance to contract with an organization who will do the work conscientiously at a reasonable price.

If the tank is used for sprinkler or fire protection service, the insurance company and the local fire department should be notified when the tank is to be taken out of service and how long it will be out, so that special provision can be made for emergency water supply in case of fire.

Painting

If the tank needs a complete repainting and if the previous paint system gave good service, it is wise to continue the use of the same system, including the corrosion inhibitive primer, intermediate, and topcoats. If the previous paint system gave unsatisfactory performance, the selection should be based upon the recommendations of the Steel Structures Painting Council in their recently published "Painting Manuals."[2] This Council is made up of representatives of 19 national associations or technical societies, including, of particular interest here, the American Water Works Association, American Institute of Steel Construction, National Association of Corrosion Engineers, National Paint Varnish and Lacquer Association, and the Federation of Paint and Varnish Production Clubs.

Volume 1 of the "Painting Manual" includes a chapter entitled "The Painting of Steel Tanks." Volume 2



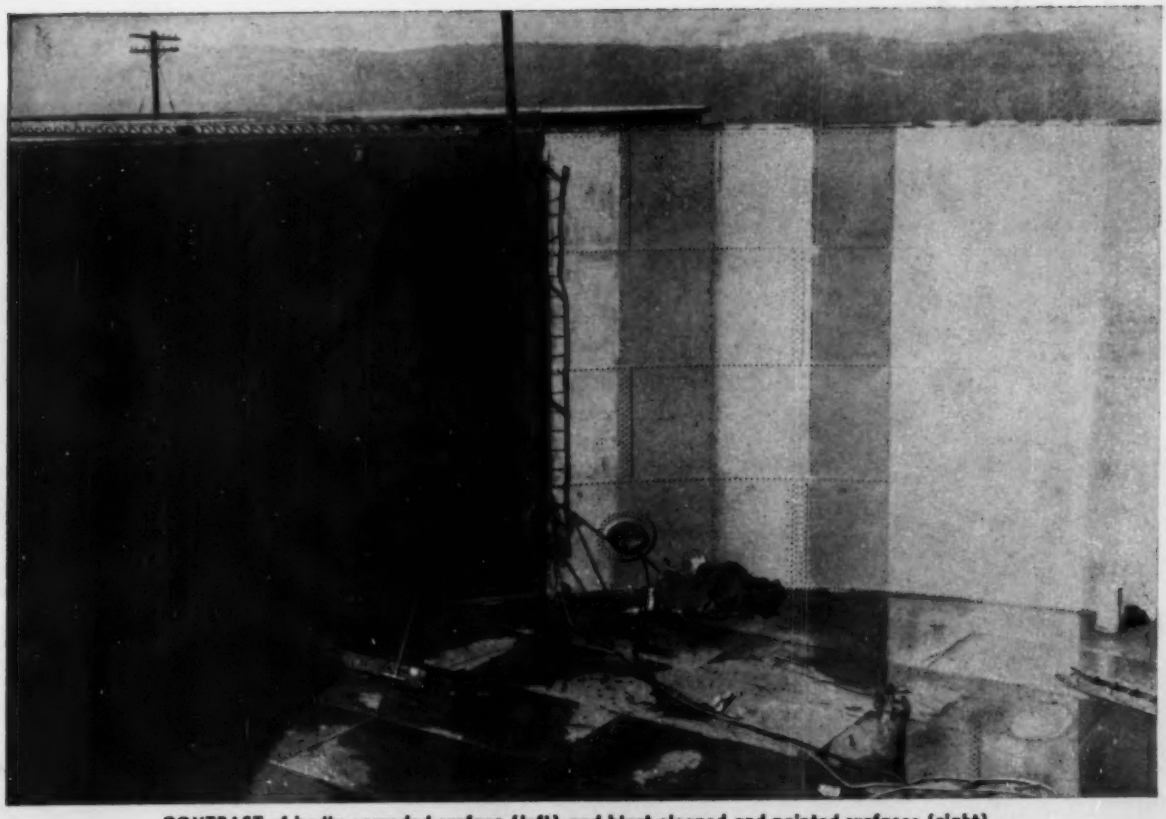
BLAST CLEANING badly corroded steel tank. Blast machine at center. Movable scaffold on castors can be dismantled for removal through man-hole. Note blast-cleaned area at left.

was published to fulfill the need for specific recommendations for the painting of various types of steel structures, to supplement the general recommendations of good practice found in Volume 1. Included are nine SSPC Specifications on surface preparation, covering wire brushing, blasting, pickling, etc. There are four SSPC surface pretreatment specifications, covering wetting oils, vinyl washcoats, and hot and cold phosphate treatments. There are thirteen SSPC primer specifications and seven SSPC intermediate and/or topcoat specifications, as well as an extensive index of Federal, Military, and ASTM specifications on paint.

TABLE I

Recommended Paint Systems

Schedule	A	B	C	D	E
(A) INTERIOR SURFACES					
SSPC Paint System No.	SSPC-PS4-55T	SSPC-PS3-55T	SSPC-PS3-55T	SSPC-PS3-55T	SSPC-PS1-55T
Surface preparation	Blast	Blast	Blast	Blast	Wire brush
Pretreatment	Vinyl washcoat	Vinyl washcoat	None	None	None
Primer(shop or field)	Vinyl red lead	Vinyl red lead	Phenolic chromate	Phenolic red lead	L. O. red lead
Intermediate coat	Vinyl red lead	Phenolic enamel	Phenolic enamel	Phenolic red lead	Red lead-litharge
Topcoat	Vinyl aluminum	Phenolic enamel	Phenolic enamel	Phenolic red lead	Red lead-litharge
(B) EXTERIOR SURFACES					
SSPC Paint System No.	SSPC-PS4-55T	SSPC-PS2-55T	SSPC-PS2-55T	SSPC-PS2-55T	SSPC-PS1-55T
Surface preparation	Blast	Blast	Blast	Blast	Wire brush
Pretreatment	Vinyl washcoat	Vinyl washcoat	None	None	None
Primer (shop or field)	Vinyl red lead	Vinyl red lead	Phenolic chromate	Phenolic red lead	L. O. red lead
Intermediate coat	Vinyl red lead	Alkyds	Alkyds	Alkyds	Alkyds
Topcoat	Vinyl-alkyds	Alkyds	Alkyds	Alkyds	Alkyds



CONTRAST of badly corroded surface (left) and blast-cleaned and painted surfaces (right). The grey strips have been blasted, but not yet painted.

There are nine broad SSPC specifications covering paint systems, covering oil base, alkyd, phenolic, vinyl, bitumastic, etc., for various exposure conditions, such as "normally dry but exposed to weather," "frequently wet or exposed to high humidity," "continuously wet or immersed in fresh water," etc.

These two volumes reflect the enormous task of the correlation of the best factual data and experience on the technical, practical, and economic aspects of paint protection of steel structures such as water tanks. The SSPC Specifications are earnestly recommended for attention. The incorporation or even partial use or reference thereto, of these specifications by the purchaser of a water tank, by maintenance superintendents, engineers, or other authorities, in the technical provisions of a repainting contract, cannot help but result in better performance and service for the tank owner.

TABLE 2

Specifications for Painting and Surface Preparation

Item	Pertinent Specifications
Blast cleaning	SSPC-SP-52T, "Commercial Blast Cleaning"
Wire brushing	SSPC-SP2-52T, "Hand Cleaning," or
Tool Cleaning	SSPC-SP3-52T, "Power Tool Cleaning"
Vinyl washcoat	SSPC-PT3-53T, "Basic Zinc Chromate-Vinyl Butyral Washcoat"
Vinyl red lead	MIL-P-15929A, "Primer, Vinyl Red Lead Type"
Vinyl aluminum	SSPC-Paint 8-55T, "Aluminum Vinyl Paint"
Vinyl-alkyds	Wide choice of color and shade; see p. 198, SSPC Volume 2.
Phenolic chromate	Pittsburgh-Des Moines S16482 (proprietary)
Phenolic enamel	Pittsburgh-Des Moines F16502 (proprietary)
Phenolic red lead	TT-P86a-Type IV, "Paint, Red Lead, Phenolic"
L. O. red lead	TT-P86a-Type I, "Paint, Red Lead, Linseed Oil"
Red lead-litharge	TT-P86a-Type I, plus litharge
Alkyds	Wide choice of color and shade, including: SSPC-Paint 101-55T, "Ready-to-Mix Aluminum Alkyd" SSPC-Paint 102-55T, "Black Alkyd Paint" SSPC-Paint 104-55T, "White or Tinted Alkyd Paint"
Application	SSPC-PA1-53T, "Shop, Field, and Maintenance Painting"

Paint Systems

There are no foolproof paint systems for the protection of steel tank surfaces. After more than a quarter century of research and testing of surface preparation, pretreatment, paints, paint systems, and paint application, in the laboratories of the author's company and in actual service, the paint systems given in Table 1 have been found to give very good performance under average service conditions[3,4,5,6].

These paint schedules are consistent with the SSPC recommendations. Schedules D and E will be recognized as being in conformance with AWWA recommendations in their

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In these compact but complete tables, data are furnished on the various types of elevated steel tanks, and on steel reservoirs. For full information as to the application of these tanks, for designs, for specifications, or for estimates, write—without obligation to our nearest office.

TABLE I PEDESTAL SPHERES

Capacity U. S. Gallons	Tank Dimensions		Tower Height
	D	V	
10,000	14'6"	13'0"	As Required
25,000	19'6"	15'0"	As Required
40,000	22'6"	17'9"	As Required
50,000	24'0"	19'6"	As Required
75,000	27'3"	24'0"	As Required
100,000	30'0"	25'0"	As Required
150,000	34'6"	27'3"	As Required
200,000	38'0"	31'0"	As Required
250,000	41'3"	31'9"	As Required
300,000	44'0"	33'0"	As Required
500,000	52'6"	37'6"	As Required

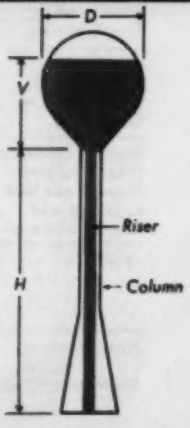

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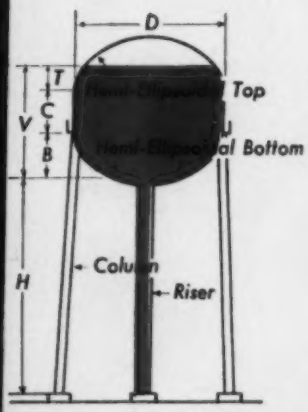
TABLE II DOUBLE ELLIPSOIDAL TANKS



Capacity U.S. Gallons	Tank Dimensions					Balcony Width	No. of Col.	Radial Bevel of Columns	Tower Height H
	D	V	B	C	T				
25,000	18'0"	14'4⅜"	4'9"	6'0¼"	3'7¼"	24"	4	1:12	See note**
30,000	18'0"	17'0"	4'9"	8'7¾"	3'7¼"	24"	4	1:12	See note**
40,000	20'0"	18'6⅝"	5'2⅜"	9'4¼"	4'0"	24"	4	1:12	See note**
50,000	24'0"	16'8⅛"	6'4⅛"	5'6⅜"	4'9⅜"	24"	4	1:12	See note**
60,000	24'0"	19'7½"	6'4⅛"	8'5⅜"	4'9⅜"	24"	4	1:12	See note**
75,000	26'0"	21'2⅛"	6'10½"	9'1⅛"	5'2⅜"	24"	4	1:12	See note**
100,000	30'0"	21'0⅞"	8'11"	6'1⅞"	6'0"	24"	4	1:12	See note**
125,000	32'0"	23'2⅛"	9'4¼"	7'5⅛"	6'4¾"	24"	4	1:12	See note**
150,000	34'0"	24'9¾"	9'10½"	8'1⅝"	6'9⅝"	24"	4	1:12	See note**
200,000	36'0"	29'4½"	10'6⅛"	11'8"	7'2⅜"	24"	4	1:12	See note**
250,000	40'0"	30'10½"	11'10½"	8'6"	10'6"	30"	6	1:20	See note**
300,000	44'0"	30'9"	13'0½"	7'11⅞"	9'8⅝"	30"	6	1:20	See note**
400,000	48'0"	34'3⅜"	14'7"	11'0"	8'8⅜"	30"	6	1:20	See note**
500,000	50'0"	39'0⅞"	15'6⅝"	15'5⅝"	8'0⅝"	30"	8	1:20	See note**
500,000	55'0"	29'11"	12'0"	10'11"	7'0"	30"	8	Vertical*	See note**
750,000	60'0"	41'7⅝"	18'0"	11'10⅝"	11'9"	30"	8	Vertical*	See note**
750,000	65'0"	37'0⅜"	20'1⅞"	6'5"	10'5½"	30"	8	Vertical*	See note**
1,000,000	65'0"	47'1¼"	20'1⅞"	16'5⅞"	10'5½"	30"	10	Vertical*	See note**
1,000,000	70'0"	42'6½"	23'0"	10'9½"	8'9"	30"	10	Vertical*	See note**
1,250,000	70'0"	51'2¾"	23'0"	19'5¾"	8'9"	30"	12	Vertical*	See note**
1,500,000	70'0"	59'10⅞"	23'0"	28'1⅞"	8'9"	30"	12	Vertical*	See note**

*Standard practice is to make columns vertical for Double Ellipsoidal Tanks whose diameter exceeds 50 ft. However their columns may be inclined if desired, in which case their radial bevel would be 1:20.

**Standard tower heights (H) are as follows:
Up to 50 ft. in even 2 ft. intervals, from 50 ft. to 100 ft. in even 5 ft. intervals, and over 100 ft. in even 10 ft. intervals. Most common standard tower heights are 75 ft. and 100 ft.

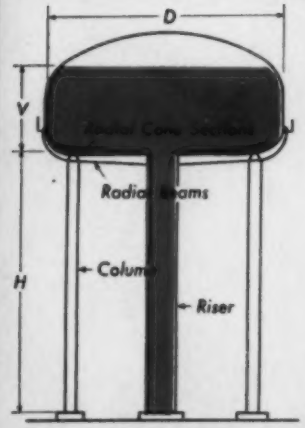


TABLE III RADIAL CONE BOTTOM TANKS

Capacity U.S. Gallons	Tank Dimensions		Number of Columns	Tower Height H
	D	V		
300,000	53'0"	20'0"	8	As Required
500,000	60'0"	25'0"	8	As Required
750,000	73'0"	25'0"	8	As Required
750,000	67'0"	30'0"	8	As Required
1,000,000	85'0"	25'0"	10	As Required
1,000,000	77'0"	30'0"	10	As Required
1,000,000	71'0"	35'0"	10	As Required
1,250,000	95'0"	25'0"	12	As Required
1,250,000	87'0"	30'0"	12	As Required
1,250,000	80'0"	35'0"	12	As Required
1,250,000	74'0"	40'0"	12	As Required
1,500,000	103'6"	25'0"	12	As Required
1,500,000	95'0"	30'0"	12	As Required
1,500,000	88'0"	35'0"	12	As Required
1,500,000	81'6"	40'0"	12	As Required
2,000,000	108'6"	30'0"	16	As Required
2,000,000	101'0"	35'0"	16	As Required
2,000,000	94'0"	40'0"	16	As Required
2,500,000	121'6"	30'0"	16	As Required
2,500,000	112'0"	35'0"	16	As Required
2,500,000	105'0"	40'0"	16	As Required
3,000,000	123'6"	35'0"	20	As Required

TABLE IV
STEEL RESERVOIRS

Capacity in U. S. Gallons	Diameter	Height
50,000	20'	21' 6"
60,000	22'	21' 6"
75,000	24'	22' 6"
100,000	26'	25' 6"
150,000	30'	28' 9"
200,000	34'	29' 9"
250,000	38'	29' 9"
300,000	42'	29' 3"
400,000	46'	32' 6"
500,000	50'	34' 6"
750,000	60'	35' 9"
1,000,000	70'	35' 0"
1,500,000	80'	40' 3"
2,000,000	95'	38' 3"
2,500,000	110'	35' 6"
3,000,000	120'	35' 9"
4,000,000	130'	40' 9"

This 20-page illustrated brochure, "Modern Water Storage in Elevated Steel Tanks," presents the broad range of PDM Tanks for every application. Factors of importance in selection are included, together with many installation pictures and a comprehensive list of basic and special accessory equipment. Write for your free copy.

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Specification D102-52. The pertinent specifications covering the surface preparation, pretreatment, primer, intermediate coat, and topcoat, and their application, are given in Table 2. All of the paints listed therein are readily available from many sources, but none are trade sale or shelf items. Some of the paints are available as proprietary brands, but all are the so-called specification paints which are formulated for specific applications.

Paint schedule A is a complete vinyl system. All coats must be sprayed, preferably by painters who have had experience with lacquer-type coatings. There are proprietary brand vinyl paints available which contain the same film-forming ingredients as the standard spraying formulations, but which include higher boiling point solvents for brush application. Spraying with vinyls does not result in paint sticking on nearby autos or other structures, because the overspray dries within a short distance.

Paint Schedule B is vinyl shop primed but non-vinyl field paint system. It is used where local painters with vinyl or lacquer experience are not available. Striping and spotting with the "shop" pretreatment and primer is done by flow brushing.

Paint Schedule C has been one of our best standards for about 20 years and is useful where a low initial cost is necessary. The interior phenolic topcoat must be applied over the phenolic intermediate coat within 12 to 14 hours to get satisfactory adhesion between these two coats. The topcoat paint must otherwise be reduced with strong solvent, such as cellosolve or methyl isobutyl ketone, using not more than one pint per five gallons of paint, to soften the intermediate coat.

Paint Schedule D is the AWWA phenolic red lead system. The same "adhesion" precaution applies as for Schedule C, as well as for all phenolic systems.

Paint Schedule E is the AWWA linseed oil-red lead system, and is the only system which does not require optimum surface preparation, as by blasting. Litharge is added to the red lead paint, just prior to application, to speed up drying and hardening.

After repainting is finished, the owner is, of course anxious to fill the tank with water. If drying and ageing depends upon natural ventilation, on the very poorly ventilated interior surfaces, and unless a large volume air mover or blower is used, the following minimum drying times, based upon past experience, are required: one day for the vinyl topcoats, one week for the phenolics, and 30 to 60 days for oil base topcoats. This obviously influences the selection of interior paint systems and, of course, the type of surface preparation.

All of the paint systems discussed comprise three coats of paint because it is felt that a total dry film thickness of at least 4 mils is necessary for satisfactory paint service life before complete repainting is again necessary. A total of 5 mils is economically justifiable, from the standpoint of maintenance cost per square foot per year. The comparative total initial costs of the various systems are of the order of $0.40, $0.35, $0.28, $0.30 and $0.29 per square foot of painted surface, respectively, corresponding to comparative maintenance of about $0.08, $0.09, $0.10, $0.10 and $0.11 per square foot per year for paint Schedules A, B, C, D and E, in that order.

This review of repainting has been confined to paint as such. Although there are many tanks protected by coatings such as wax, grease, and coal tar, hot or cold applied; by neoprene, cement linings, sprayed metal, either zinc or aluminum, with or without seal coats; and by cathodic protection, with or without painted surfaces, the large majority of maintenance is based upon paint.

Summarizing, successful and economical paint protection depends upon:

1. Selection of a suitable paint system.
2. Proper surface preparation.
3. Suitable and compatible paint materials.
4. Good application to minimum film thickness under favorable working conditions.
5. Adequate drying and ageing.
6. Maintenance of the paint system by alert inspection and spot repair or complete repainting.

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1. Jackson, J. O., "Guide for Water Tank Maintenance Inspection," Water and Sewage Works, (Apr. 1951).
2. "Painting Manuals," Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh 13, Pa.
3. "Final Report of Ambridge Test of Paints for Water Tanks Interiors," Tech. Bull. 3304. Pittsburgh-Des Moines Steel Co. (1933).
4. Jackson, J. O., "Experimental Studies of Tank Coating Materials." Jour. AWWA, *33*, 9, (Sept 1941).
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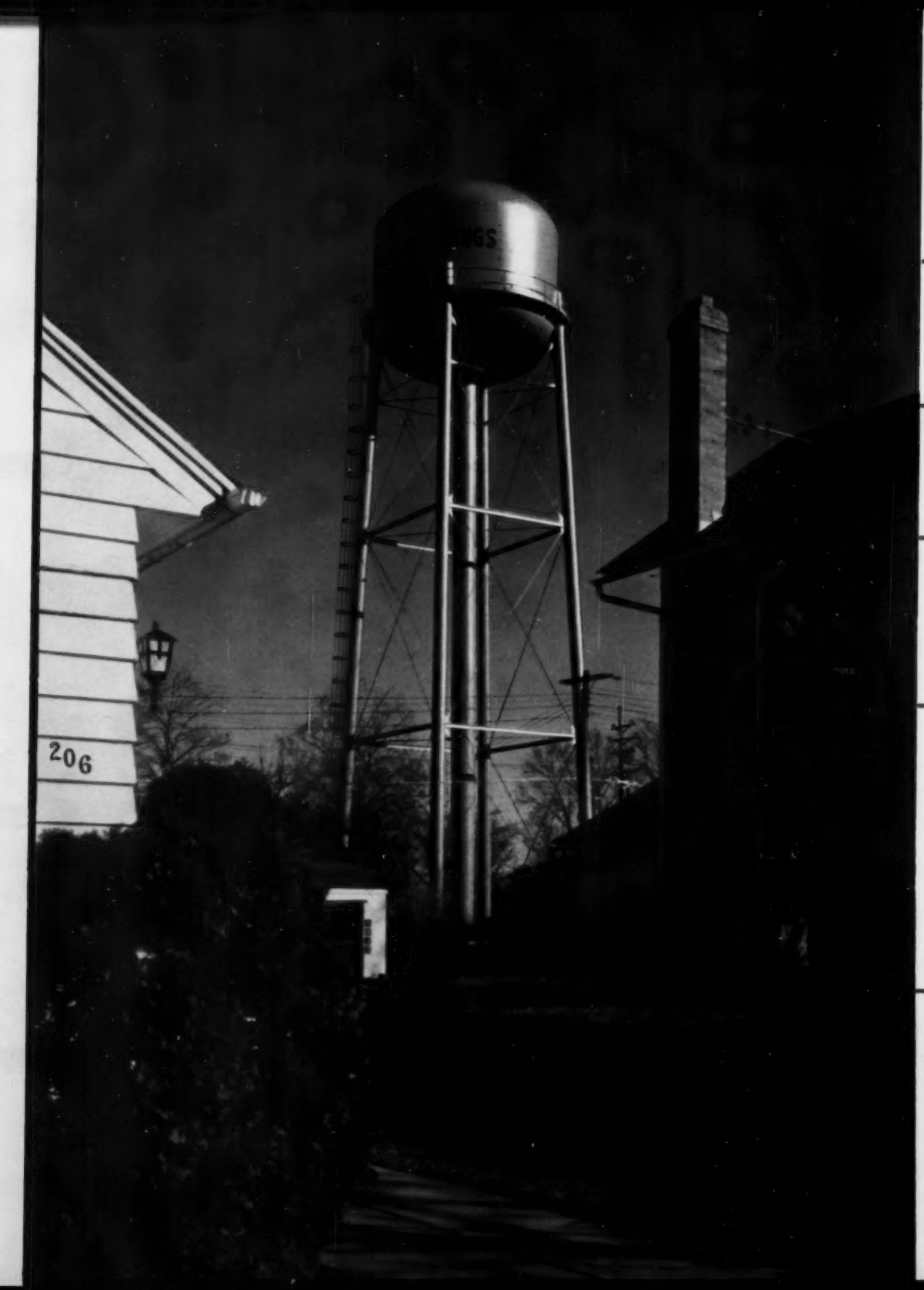

FILE REFERENCE

FACT SHEET

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How A Small Rural Community Solved Its Water Supply Problem

Dr. J. M. Brown, Village President
Arthur W. Robinson, Water Superintendent
Charles O. Herman, Village Clerk
Williams & Works
Consulting Engineers
Grand Rapids, Michigan
Raymond L. Elliott, Project Engineer
Graver Tank & Mfg. Co., Inc.
Design, Fabrication and Erection

Type: Double Ellipsoidal Elevated Tank
Capacity: 150,000 gallons
Height to Overflow: 128'
Head Range: 28'
Diameter of Tank: 32' 0"
Built to AWWA Specifications
Painted and Sterilized
Cathodic Protection and Lighting Included

THE PROBLEM

The water supply of the growing rural community of Berrien Springs, Michigan (population 1,761), was adequate for normal demands but insufficient for summer sprinkling and fire protection. Furthermore, in terms of expected population growth, the system—installed in 1914—was woefully limited. The old system would be required to meet a demand for over 2,000 gallons per minute while the capacity of the wells was limited to 1,500 gallons per minute.

THE SOLUTION

An enlarged storage supply was the answer. The purchase of a new elevated water tank of 150,000 gallons capacity to replace the existing 50,000 gallon tank was recommended. Without increasing the present pumping capacity, the larger tank provided enough storage to meet the demand of over 2,000 gallons per minute for a five hour peak period. This also assured the needed water to protect the community from fire.

Graver was selected to design, fabricate and erect the 150,000 gallon elevated water tank and to paint, sterilize, light and cathodically protect it before completion. Graver also dismantled and removed the old tank.

The teamwork between the Village officials, the Water Superintendent, and consulting engineers and Graver resulted in an excellent solution to the need for additional water at the lowest cost.

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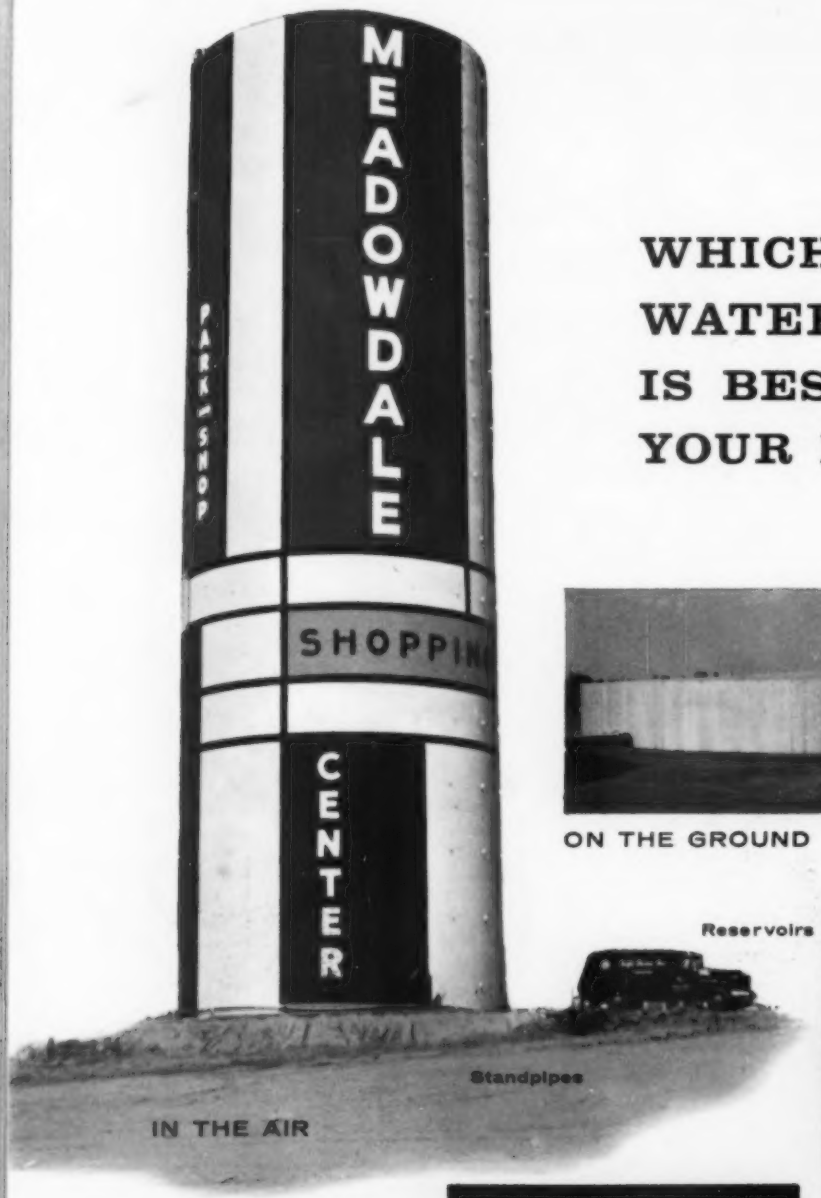

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BUILDING FOR THE FUTURE ON A CENTURY OF CRAFTSMANSHIP IN STEELS AND ALLOYS

Contents of Cylindrical Tanks

By W. F. SCHAPHORST
Mech. Engr., Newark, N.J.

FIGURING the gallons in a vertical cylindrical tank takes time, and errors are often made in longhand figuring. The accompanying chart quickly gives the number of gallons in a vertical tank of this kind, of ordinary size, and even beyond the ordinary sizes.

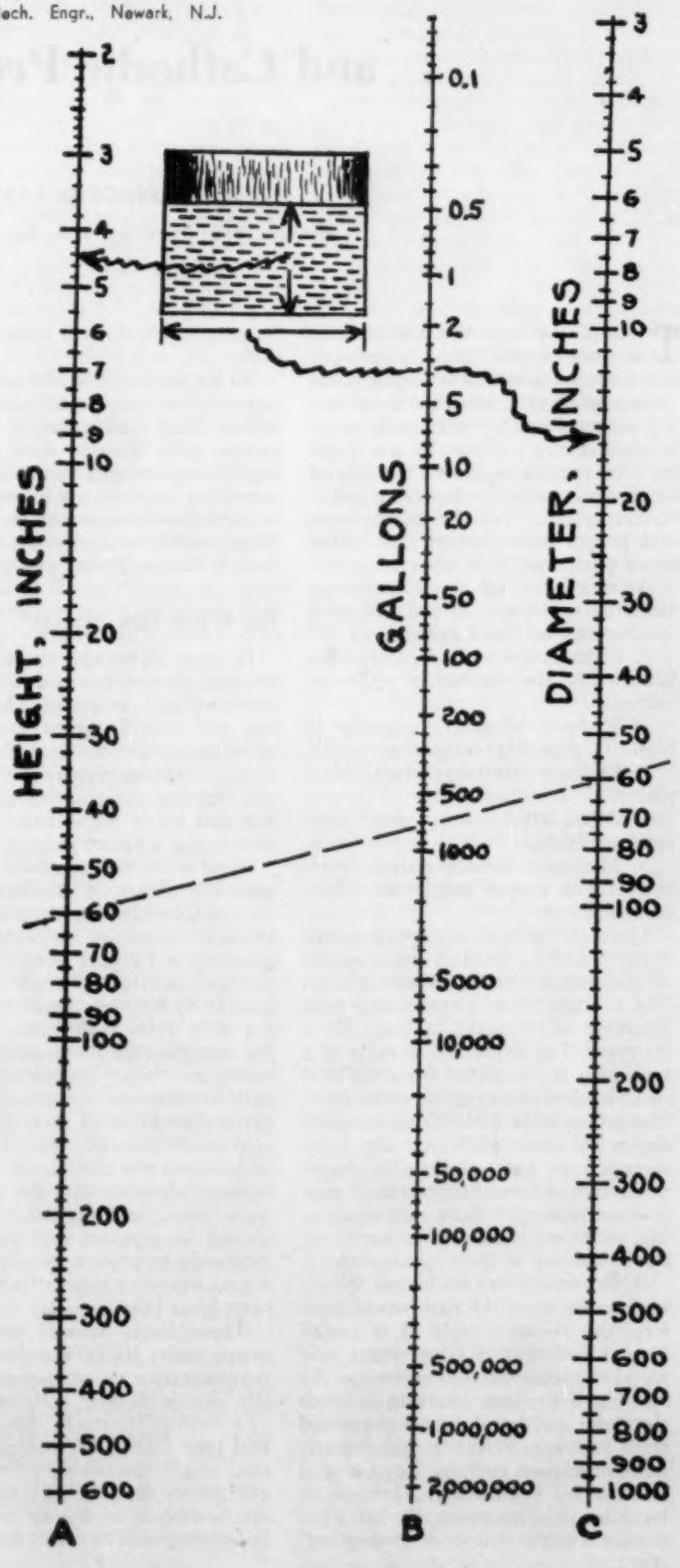
For example, how many gallons will be held by a cylindrical tank 60″ high by 60″ in diameter? The dotted line drawn across the chart shows how it is done. Connect the 60 in the height column (A) with the 60 in the diameter column (C) and the answer is shown in the volume column (B) to be very close to 740 gallons. Figure it out in longhand or on a slide rule and you will find that the answer is 733 gallons, showing that the chart is sufficiently accurate for general use over a wide range of tank sizes.

Inversely the chart may be used to figure the size of tank that will hold a certain number of predetermined gallons. Thus if a tank is wanted to hold 740 gallons, simply run any straight line through the 740 in column (B) and the intersection with column (A) gives the height, and the intersection of the same line with column (C) gives the diameter. By swinging a straight line around the desired point in column (B) the most economical height and diameter combination is readily obtained. As will be observed, there are hundreds and thousands of combinations possible to hold 740 gallons. Also, if we should have a tank 60″ in diameter and, say, 200″ high, and it should be desired to pour only 740 gallons into it, the same dotted line drawn across this chart will show that by filling the tank to a height of 60″ it will contain 740 gallons.

The range of the chart, as will be observed, is very great. It will take care of any tank all the way from 2″ in height to 600″ in height, and any diameter from 3″ to 1000″. The maximum capacity of the largest tank is given as 2,000,000 gallons. The chart is based on the U.S. standard of 231 cubic inches per gallon.

Just as an "exercise," what, for instance, must be the dimensions of a tank (can) to hold exactly one gallon? Any line through the "one" in column (B) will give combinations of two dimensions—in fact hundreds of them. One of the combinations will be found to be 6″ high by 7″ in diameter. It will also be found that a flat-shaped tank (can) 3″ high by 10″ in diameter comes very close to having a capacity of one gallon. Or, if 20″ high by 4″ in diameter this combination will hold one gallon. The number of possible combinations is endless.

If the chart is used a few times you will keep it in a convenient place in your work desk.



Water Tank Maintenance and Cathodic Protection

by CLARENCE D. LAMON
Manager, Water Works and Sewer Board, Prichard, Ala.

TODAY the care and maintenance of elevated steel tanks, standpipes and storage reservoirs are being given considerably more attention than during recent years by water works officials and city councils. In many cities they usually represent the largest single investment in the water distribution system. Yet the maintenance and proper care thereof, are sometimes postponed year after year.

Advantages of elevated storage tanks or standpipes in a distribution system may be listed as follows:

1. Reduces the size of purification facilities or the number of wells required.
2. Reduces necessary capacity of high-lift pumping equipment.
3. Reduces size of transmission mains.
4. Makes better uniform water pressure available.
5. Maintains service during interruptions in power supply or failure of equipment.

Once an elevated storage structure is built and in service, the question of maintenance arises immediately. The average life of a steel water tank structure is estimated at from 50 to 60 years. The depreciation value of a tank may be estimated from the first cost and the remaining life of the tank. For example, a $50,000 tank would depreciate about $825 annually. Even though some water works officials are not aware of annual depreciation cost, a silent destroyer daily eats away at the metal of their tanks, impairing the soundness of their investment.

This silent destroyer is rust. Eliminating the cause of rust would prolong the life of a tank. It is a well known fact that it takes water and metal to make rust and corrosion. By keeping the proper covering between the water and metal, rust is prevented from forming. Without rust there is no depreciation and the life of a tank is extended indefinitely. There is no structure which more aptly bears out the truth of the "ounce of prevention" formula than does a steel storage tank.

To assure long life and prevent the formation of deep-seated rust or corrosion, steel tanks should be given proper care. This is done by thoroughly inspecting both the inside and outside at intervals not exceeding two or three years, depending on the operating conditions and experience factors of the particular utility.

The Water Tank "Racket"

In some cities and towns the municipal government and the water works officials frequently change during the interval between one tank painting job and the next. All records and the valuable experience gained in one cleaning and painting job may be lost and be of no assistance in contemplating a future painting job.

Most water works officials are now generally aware of fraudulent practices of some unscrupulous tank maintenance companies soliciting tank painting and repair work. The high-pressure salesmen of these unscrupulous or fly-by-night firms start working on a water tank owner by claiming that they are just passing through town, and being interested in water tank maintenance observed the dangerous condition of their tank. They also may pretend that they have looked over the tank, noticed signs of leakage, observed that the sway rods were loose, and urge that the tank should be repaired and painted immediately to protect the metal before it gets worse, or before the tank blows over from heavy winds.

These firms mostly operate in towns under 10,000 population. Their representative or contact men generally have with them and present their own form of contract. They have several type forms, all worded for their advantages, usually very loosely, with guarantees that are not specific and are worthless as far as enforcement is concerned. They will also present the type of contract they think they can induce the owner to sign immediately, without giving him adequate time to thoroughly examine it or time to have it approved by a legal advisor. Usually the contract has a clause or statement that "the contract is void if not executed within twenty-four hours".

One of these forms of contract provides for the owner to furnish all materials. Another form provides for the contracting firm to furnish all materials, and they will claim that their materials meet or excel government specifications. However, the materials are generally of the lowest grade. In either form of contract that these firms present the contracting firm furnishes all labor and equipment for cleaning, repairing and painting the tank. Generally found in the fine print is a clause stating that the equipment such as air compressors, welding machines, and pneumatic tools, if needed, will be charged for at so much per hour; loose rivets will be replaced at so much each; and electric welding of pits and seams will be charged for at so much per square inch. When such an agreement is signed, it appears that this part of the contract work is merely incidental to the cleaning and painting, so as to put the tank in first class condition at what looks like a bargain price.

After one of these contractors goes to work, however, and the tank has been emptied for cleaning and painting, troubles start. They claim that they discover loose rivets that need replacing, seams and pits that need welding, and that the saucer and spider rods need extensive repair or replacing. All of this type of work was mentioned in the fine print of the contract, but was merely incidental before signing. When the work is completed the tank job has cost several times the amount proposed in the beginning; and two or three times more than a reliable responsible tank construction and repair company would

have charged to put the tank in first-class condition.

Inspection

If a water tank reaches 20 years of age or more, and it is suspected that regular inspection and maintenance on the tank has not been of the best, it is advisable to have a complete inspection made. Or if a water tank structure has been neglected and it is evident that it needs some repairs before painting, the owner should know definitely what kind of paint job is needed and what repairs are necessary before he enters into a contract to have work done.

On the basis of experience, a schedule for cleaning and painting the tank at proper intervals should be set up. A short time before the tank is to be overhauled, it should be examined. If the owner does not have someone in the organization who is capable of inspecting the tank, then some capable and competent expert not involved with a contractor or interested in the profit to be made should be consulted. Usually the tank manufacturer has experienced men for this service. For a normal charge they will submit a written report showing the condition of all parts of the structure. Be prepared, however, to empty the tank for the inspection, as this is the only accurate and complete way the interior can be inspected.

With a complete independent report on the structure, a proper form of contract can then be drawn up, together with specifications suitable for the performance of the required work. The American Water Works Association has standard specifications and recommended practices for elevated steel water tanks, standpipes, and reservoirs; painting and repainting such structures are included. "Pamphlet No. 102-53" contains recommended procedures and a list of coatings, based on experience gathered from reliable sources, for both the interior and exterior surfaces, that have been proven satisfactory

Cleaning and Preparation

More important than the application of paint, is the preparation of the metal surface before paint is applied. Underwater exposure involves very severe service for paint on the interior. As water is consumed daily, the metal is also exposed to the humidity of the air. The exterior is exposed to the hot baking sun, wind, rain, hail and snow, and in some localities the gases of smoke and fumes from industrial plants, as well as salt air along the sea coast.

The interior and exterior surfaces of water tanks or standpipes are each cleaned and painted in a similar manner. However, on each surface all rust scale, old paint scale, blisters, loose rust, dirt and any other foreign matter must be removed before applying any new covering on the metal. The same tools are generally used on interior and exterior. They are: hand scrapers, wire brushes, power scalers, power wire brushes, and flame cleaning and sand blasting equipment. Flame cleaning or sand blasting do a thorough job of cleaning all metals. These processes are quite expensive and are not included in the standard cleaning of a tank, unless they are particularly specified and the job is priced to include this type of metal cleaning and preparation.

There is a great difference in the chemical properties of both surface and ground waters in various parts of the country. Frequently, a paint that would resist the action of water in one locality would deteriorate very rapidly under the action of water in some other locality. Theoretically, any coating of paint or other substance that will keep water from contact with metal will prevent rusting.

Painting should follow as soon as possible after cleaning. Under normal mild atmospheric conditions it is best to prime all exposed bare metal surfaces within eight hours after cleaning, to prevent further rusting.

Tank Interior

Experience has shown that in practically all cases the inside surfaces of a water tank are in worse condition than the outside. Almost without exception, tank bottoms which have to be replaced on account of leaks through the steel have corroded through from the inside. This is due to neglect of cleaning out accumulated mud. It is vitally important that the inside of a tank be painted as often as the outside; if the water is corrosive, the inside may have to be painted at more frequent intervals.

When the old paint is in fair condition, only one coat may be required; after cleaning, however, certain portions of the steel will be bare. These bare spots should be painted with a patch coat of a good rust inhibitive paint before the finish coat is applied. If the surface is generally in bad condition, a complete primer coat should be applied instead of patch coating. The first coat must be thoroughly dry and hard before the second coat is applied. The same holds true with the last coating before the tank is again filled with water.

Red lead and linseed oil paint in general has given good results for this service. Asphalt paints have been found suitable for some waters, but quite unsuitable for others. Coal tar enamels also have been used and have given satisfactory results. More recently, the newly developed synthetic resin type of paint has given very good results under many conditions. In the event that two coats of paint are necessary, when using other than asphalt or coal tar enamels, a small amount of lampblack should be added to the second coat to give it a darker shade. This makes it easier to determine whether the first coat has been entirely covered by the second coat.

For many years grease coatings have been used for the interior protection of elevated tanks and standpipes. Experience has proven that a rustproof grease compound applied to steel tanks will prevent water from coming in contact with the metal in most cases for about five years or more. The advantage in using a grease compound is that a tank can be returned to service immediately after it is applied. Another advantage lies in the fact that interior and exterior work on a tank can be performed simultaneously. Still another great advantage lies in its low material cost and low labor cost for application. Yet the tank will have adequate metal protection as long or longer than other metal coverings, especially if a good prime coat is applied to new steel ahead of the grease coating.

Whenever the storage structure is emptied and entered for inspection, cleaning and painting, or for any other purpose, it should be disinfected by a standard recognized method before it is placed back in service.

Exterior

Exterior surfaces of elevated tanks and standpipes are subject to constant exposure to general weather conditions. To secure a first class appearance and durable job requires more skill than is needed for the interior.

All exterior metal must be carefully cleaned. Then if the tank is in a very run down condition and cleaning has removed a large portion of the paint, it is economical to apply a complete coat of rust inhibitive primer, regardless of what kind of color or finish coat is later applied. Should the surface be in fair condition, and only small areas of bare metal have been exposed by cleaning, it is economical to patch coat the tank.

If the old paint on the outside of the tank is dark and a light coat is desired, it will be necessary to apply

CHICAGO BRIDGE & IRON COMPANY

SOUND ENGINEERING, MODERN DESIGN, STEEL CONSTRUCTION, TO AWWA SPECIFICATIONS

Horton® all-welded steel elevated tanks provide dependable gravity pressure water to insure the following benefits for growing communities:

- **Reduced pressure variations**
- **Increased water pressure**
- **Reduced pumping cost**
- **Fire and emergency reserves**
- **Trouble-free service life at a minimum of maintenance**
- **All CB&I structures are built to AWWA Specifications**

A variety of modern, elevated structures are built by CB&I in a wide range of capacities.

The WATERSPHERE® combines functional beauty and prestige with maximum storage capacity in an easy-to-paint, easy-to-maintain structure. Available in capacities ranging from 25,000 to 250,000 gallons.

The WATERSPHEROID® differs from the Watersphere only in shape and capacity of the structure. Capacities from 25,000 to 500,000 gallons. Base of the column in either structure can be used as pump or storage house. *Write for Watersphere and Waterspheroid Bulletin.*

The ELLIPSOIDAL-BOTTOM TANK features a relatively large diameter and shallow depth to provide pleasing proportions and reduced variation in pressure as water is used from the tank. *See table for capacities.*

The RADIAL-CONE TANK provides elevated storage in a tank of large capacity with a low range in head, has smooth lines, and is easy to maintain. Available in capacities up to 3,000,000 gallons. Can be furnished with or without a balcony.

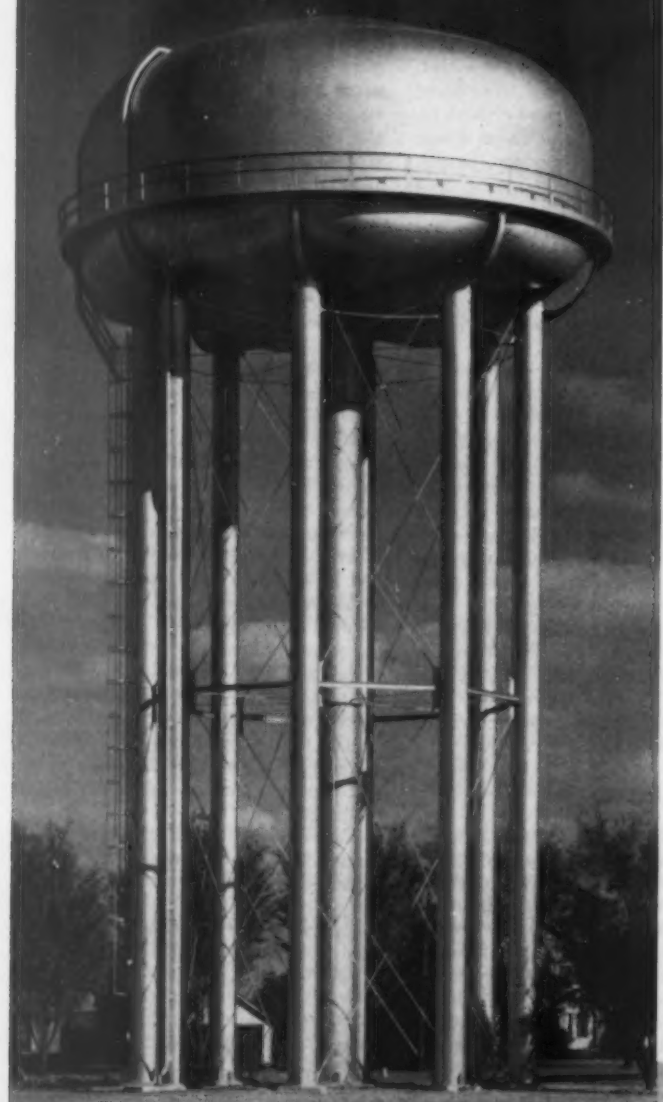
The ELEVATED HORTONSPHEROIDAL TANK is used where a large elevated storage capacity (1,000,000 to 3,000,000 gallons) is needed. Can be built with a large central riser in a smooth or fluted design—or central portion can be supported on an inner circle of columns. *Write for bulletin describing large capacity elevated tanks.*

STANDPIPES Horton standpipe and reservoir designs have proven particularly adaptable to special architectural treatment in many communities (see photo at right).

The STEEL RESERVOIR OR STANDPIPE provides gravity pressure where natural elevations are available or where large storage capacity is needed at ground level. A variety of roof types including cone, ellipsoidal, umbrella, dome, etc., can be furnished to suit specific requirements.

CB&I tanks can be designed to meet *any* size or capacity requirements.

WRITE FOR literature on any of the tank designs shown here.



500,000-gallon Horton Radial-cone tank serves the water requirements of growing Appleton, Wisconsin.

CB&I CRAFTSMANSHIP IN STEEL

10,000,000-GALLON HORTON RESERVOIR serves city of Spokane, Washington. Is 240 ft. in diameter by 32 ft. high . . .

MS49C

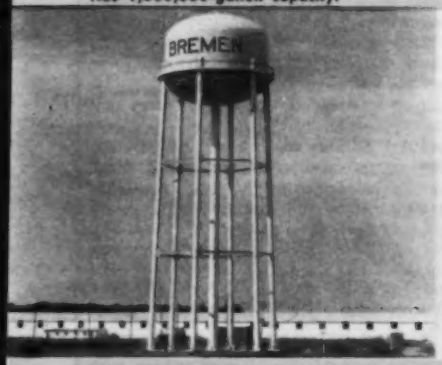
For details circle 538 on inquiry card

HORTON® TANKS for Municipal Service

HORTONSPHEROIDAL elevated tank at Berkeley, Michigan is 76-ft. to bottom. Has 1,000,000-gallon capacity.

RADIAL-CONE elevated tank at Evansville, Indiana is 100-ft. to bottom. Has 500,000-gallon capacity.

ORNAMENTAL welded steel standpipe at Madison, Wis.; capacity, 3,000,000-gal.



ELLIPSOIDAL-BOTTOM tank at Bremen, Indiana is 105-ft. to bottom. Has 300,000-gallon capacity.

WATERSPHERE at Aroma Park, Illinois, has 50,000-gal. capacity. Is 100-ft. to bottom.

WATERSPHEROID at Elmhurst, Illinois is 110-ft. to bottom. Has 500,000-gal. capacity.

HORTON PICKLING PROCESS. Special treatment in CB&I plants removes mill scale and applies thin iron phosphate coating which acts as bonding agent between metal and coat of primer paint which is applied while metal is hot. Unique process insures low maintenance and longer paint life. *Write for a descriptive bulletin.*

STEEL PIPING, STEEL PLATE WORK. All CB&I plants are equipped to build and assemble welded steel pipe 60 in. in diameter or larger for water intake and transmission lines. Self-supporting steel smokestacks, tanks and hoppers for coal or chemicals and other special types of heavy steel platework can also be furnished by CB&I.

WASH WATER TANKS. Horton Radial-Cone or Ellipsoidal-bottom tanks are widely used at filtration plants for washing filter beds.

FOR ADDITIONAL INFORMATION. We will be pleased to discuss advantages of various designs and submit estimates to waterworks engineers or municipal officials. Write or call our nearest office for consultation on special designs. Five strategically located, specially equipped CB&I plants can serve *your most specific* requirements.

WELDED ELLIPSOIDAL-BOTTOM ELEVATED TANK SIZES

Capacity in U.S. Gals.	Diam. of Tank	Range in Head	Capacity in U.S. Gals.	Diam. of Tank	Range in Head
15,000	15′ 6″	11′ 0″	125,000	30′ 0″	25′ 6″
20,000	15′ 6″	14′ 9″	150,000	32′ 0″	27′ 6″
25,000	18′ 0″	14′ 0″	200,000	36′ 0″	29′ 6″
30,000	18′ 0″	16′ 6″	250,000	40′ 0″	29′ 0″
40,000	20′ 0″	18′ 0″	300,000	43′ 0″	30′ 0″
50,000	22′ 0″	19′ 0″	400,000	46′ 0″	35′ 0″
60,000	24′ 0″	19′ 0″	400,000	50′ 11″	30′ 0″
75,000	26′ 0″	21′ 0″	500,000	50′ 0″	37′ 6″
100,000	28′ 0″	24′ 0″	500,000	56′ 0″	30′ 0″

RADIAL-CONE BOTTOM ELEVATED TANK SIZES

Capacity in U.S. Gals.	Diam. of Tank	Range in Head	Capacity in U.S. Gals.	Diam. of Tank	Range in Head
500,000	60′ 4″	25′	1,500,000	96′ 0″	30′
750,000	74′ 3″	25′	1,500,000	88′ 0″	35′
750,000	67′ 6″	30′	2,000,000	102′ 0″	35′
1,000,000	86′ 0″	25′	2,000,000	112′ 0″	30′
1,000,000	78′ 0″	30′	2,500,000	114′ 0″	35′
1,000,000	71′ 6″	35′	3,000,000	126′ 0″	35′
1,500,000	104′ 0″	25′	3,000,000	117′ 0″	40′

HORTONSPHEROIDAL tanks furnished in capacities of 1,000,000 to 3,000,000 gallons and in dia. of 87′6″ to 120′0″. Range in head from 25 ft. (1,000,000-gal. cap.) to 40 ft. (3,000,000-gal. cap.).

Chicago Bridge and Iron Company

Atlanta 3	2104 Healy Bldg.	Detroit 26	1537 Lafayette Bldg.	Salt Lake City 4	523 W. 17th South St.
Birmingham 1	1568 North 50th St.	Houston 2	2117 C & I Life Bldg.	San Francisco 4	1539—100 Bush St.
Boston 10	1023-201 Devonshire St.	New York 6	3392—165 Broadway	Seattle 1	1323 Henry Bldg.
Chicago 4	2470 McCormick Bldg.	Philadelphia 3	6 Penn Center Plaza	South Pasadena	712 Fair Oaks Ave.
Cleveland 14	2239 Midland Bldg.	Pittsburgh 19	3226 Alcoa Bldg.	Tulsa 3	1608 Hunt Bldg.

Plants in: BIRMINGHAM • CHICAGO • SALT LAKE CITY • GREENVILLE, Pa., • NEW CASTLE, Del. • *In Canada:* HORTON STEEL WORKS Limited, Toronto, Ontario.

For details circle 539 on inquiry card

SUGGESTED PROPOSAL, CONTRACT AND SPECIFICATIONS

For the Cleaning, Painting and Repairing of Steel Water Storage Tanks

General Conditions and Instructions to Bidders

Sealed proposals will be received by the ...., at ..... until ..... o'clock on ....., for furnishing all labor, materials and equipment necessary and required to thoroughly clean and paint both the exterior and interior surfaces of the ....gallon steel water storage tank located on..... ....., all in accordance with the contract and specifications covering this work.

Bidders must secure their information as to the conditions of the tank and all local conditions effecting the work prior to submitting their proposal.

Work must be begun promptly after the award of the contract and within such time as stated by the successful bidder, and be completed by the time named by said bidder.

Bidders are notified that the price bid must include everything described in the specifications. No extras of any kind will be allowed unless ordered in writing by the ....

The bidder must satisfy the Company of his practical and financial ability to perform the work bid upon. The bidder must attach to his proposal the names of the owners of three structures, of the same type, for which the bidder has successfully completed work of the nature outlined in the attached specifications, within the last 12 months.

Payment for this work will be made in cash, and in accordance with the contract and specifications.

The right is reserved to reject any or all bids or to accept any bid considered advantageous to the owner.

Proposal

..... (Date)

To .....:

We hereby propose to furnish all labor, materials and equipment necessary and required to throughly clean and paint both the exterior and the interior surfaces of the steel water storage tank located on ....., all in accordance with the general conditions, contract and specifications, which we have examined, for the lump sum of ..... $.....

If awarded the contract, we will begin work ..... days after receiving notice of the award, and will complete said work within ..... calendar days after receiving notice of the award.

Respectfully submitted,

.....

.....

Specifications

Definition

Whenever the word "Owner" is used, it shall be held to mean the ....., its Superintendent, Engineer or other authorized agent. Whenever the work "Contractor" is used, it shall be held to mean the Contractor or Firm under contract to do the work herein specified.

Suspension of Work

The Superintendent, or Engineer, or authorized Agent, of the owner shall have the right to stop or suspend the work at certain points if in his opinion public need demands it. In case of any suspension, the time within which the Contractor is required to complete the work shall be extended by as many days as the same was thus suspended.

Alteration

Any alterations or modifications of this work here contracted for shall be made only by a written agreement between the Superintendent, Engineer, or authorized agent and the Contractor before the alterations or modifications have been started.

Extra Work and Material

No claims for any extra work or materials will be allowed, unless it is ordered in writing by the owner and the price to be paid is agreed upon by a written agreement before the work is done or material furnished.

Compensation Insurance

The Contractor shall provide adequate workmen's compensation insurance for all labor employed by him on the project, and shall comply with the Workmen's Compensation Laws of the State of ....., and shall give proof of such insurance, satisfactory to the owner.

Public Liability Insurance

The Contractor shall promptly protect the work, and shall hold the owner harmless from all damages occurring in any way by his acts or neglect, or that of his agents, employees or workmen, or for damages due to injury to his employees, or others during the progress of the work. He will also be required to furnish a certificate of insurance showing the Contractor to have a policy of not less than $10,000 covering property and public liability. He will also defend in court by his own counsel any suit brought against the ..... for any property damage or personal liability in connection with the work covered by this contract and outlined in the specifications.

The Contractor is hereby cautioned to exercise precaution in protecting all property owned by the Company or adjacent thereto during the progress of his work.

Payment

Payment will be made in cash upon completion of work following inspection and acceptance of the work by the Company.

Inspection of Work

The work shall at all times be subject to inspection, but such inspection shall not relieve the Contractor from any obligation to perform said work in accordance with the specifications or any modifications thereof, as herein provided, and work not done strictly in accordance with the specifications shall be corrected and made good by the Contractor whenever so ordered by the Superintendent, Engineer or authorized agent of the owner, without reference to any previous oversight or error in inspection.

Preparation of Surfaces—Exterior and Interior

If the old paint is in good condition, adheres tightly to the steel, and is hard and not too thick, it may be left on. All rust, loose mill scale and loose paint shall be removed by means of scalers or scrapers and wire brushes (preferably power driven), emery cloth or sandpaper. Special care shall be used to clean all pits and roughened areas. In places where blisters or rust has occurred, the steel shall be cleaned until it is bright, either by wire brushes and scrapers or by the use of hand or power sanders. All foreign material, rust and loose paint shall be removed, and any old paint which has been allowed to remain shall have a clean surface and be tight to the steel.

All rust, scale and sediment collected inside of the tank bottom shall be entirely removed from the tank and the inside surfaces swept clean. In cleaning elevated tanks, such rust, scale, etc., shall be lowered to the ground by acceptable means and disposed of in a manner satisfactory to the owner.

Paint shall not be applied when the temperature is below 40° F. The surface shall be free of frost or dampness when paint is applied. No paint shall be applied unless good weather prevails, nor such applications be started if inclement weather threatens.

All paint shall be evenly spread and throughly brushed out. The highest standards of workmanship shall prevail. In all instances, the application of paint shall be satisfactory to the en-

gineer-in-charge or to the inspector delegated by him. Particular attention shall be given to rivet heads, edges, welds, etc.

Workmanship

The paint shall be of the proper consistency for a brush application. Thinner shall not be added under normal conditions. In the cooler weather it may be necessary to thin the paint. If so, not more than one pint per gallon shall be added. For a spray application, thinner may be required for the paint to pass through the spray equipment. Only enough thinner shall be added to permit the paint to pass through the spray equipment. In no case shall it exceed one pint of thinner. "Mineral Spirits" is the suggested thinner, when required.

Repairs

It shall be the duty and responsibility of the contractor to notify the owner of any loose rivets, open seams, etc., before the application of paint so that the owner can make the necessary repairs with his own employees, or to authorize the contractor in writing to proceed with this work at a total price agreed upon in writing.

Sanitary Requirements

The contractor and all workmen employed by him shall conduct all operations in a clean and sanitary manner. No nuisance shall be committed in a tank; the workmen shall either use proper waste receptacles or leave the tank whenever necessity arises.

The tank owner, after work of any nature is done in a tank, is charged with satisfying himself that the tank interior is clean and sanitary before the tank is returned to service. Although a contractor may be required by his contract to clean all painted surfaces thoroughly before a tank is restored to service, it is the ultimate responsibility of the tank owner to give the tank a final field inspection or to require such laboratory tests of the quality of water held (for test purposes) in the tank as will demonstrate the good sanitary condition of the tank interior.

Inspection

The owner shall inspect the painting as it is being done or employ an inspector to do so. Payment for painting shall be made only after the owner has satisfied himself directly that the painting is satisfactory; or after an inspector's report has been filed with the owner certifying that the painting has been done properly and in accordance with the requirements of the contract.

It is in the mutual interest of the owner and the contractor that such inspection be made promptly.

Ventilation

The contractor must provide adequate ventilation while painting the interior surface of a tank. The ventilation shall be adequate to remove fumes and prevent injury to workmen or the possibility of accumulating volatile gases.

Paint

Paint shall be delivered to the job site in factory-sealed containers, with the manufacturer's labels affixed to the containers showing the manufacturer's name, brand, color, identification number, etc.

The paints used shall be recognized as being suitable for the protection of water storage equipment. If required by the owner, the contractor shall furnish the owner with a list of 5 water tanks painted with the paints the contractor proposes to use, from which not less than 6 years' protection was secured on water tanks.

If the paint used has a graphite pigment, which is preferred, only the use of natural flake silica graphite will be permitted.

Exterior

Prime Coat: .....
.....
Intermediate Coat: .....
.....
Finish Coat: .....
.....

Interior

Prime Coat: .....
.....
Intermediate Coat: .....
.....
Finish Coat: .....

Contract

This Contract, entered into this ..... day of .... 19, by and between the ..... and .... Contractor, for furnishing labor, materials and equipment necessary and required to thoroughly clean and paint the interior surfaces of the steel water storage tank located on ..... for the consideration of .... Dollars ($ .....) in strict accordance with the requirements of the accompanying specifications which are made a part hereof.

Witnesseth, that the said Contractor has agreed and by these presents does agree with the ..... for the consideration named, to furnish all labor, materials, and equipment and do all the work of whatever nature necessary to complete in a workmanlike manner and according to the specifications and subject to all the terms and to the approval of the ....

In case the Contractor shall be required to do any work of a class not provided for in the bid and this contract, said Contractor agrees that the amount to be allowed him shall be fixed by written agreement between the said Contractor and the .....before the work is commenced, and in case of failure to agree, then by some party to be agreed upon by said ..... and the Contractor.

That said Contractor agrees that the Superintendent, Engineer or other authorized agent of the ..... may cause any work or materials not in accordance with the specifications and the contract to be replaced at the expense of the contractor.

The ..... agrees and binds itself upon the completion of the work to the approval of the Superintendent, Engineer, or other authorized agent to pay to said Contractor the amount of money due under this agreement. Full payment will be made upon the acceptance of the work.

Form of Bond

KNOW ALL MEN BY THESE PRESENTS: That .... as Principal, and ..... as Sureties, are held and firmly bound unto the ..... of ....., in the sum of ..... Dollars, for the payment of which, well and truly to be made, we do hereby severally bind ourselves our heirs, executors, and administrators, firmly by these presents.

THE CONDITION OF THIS OBLIGATION is such that, whereas the said above-named principal did on the .... day of ..... 19 ....., enter into the foregoing agreement is made a part of this bond, the same as though fully set forth herein:

NOW, if the said Contractor in the said foregoing statement shall well and truly execute all and singular the stipulations of said agreement by him to be executed, and shall pay all just and legal claims for labor performed upon and for materials furnished for the work specified in said agreement, then this obligation to be void, otherwise to remain in full force and virtue in law; we agreeing and hereby consenting that this undertaking shall be for the use of any laborer or material men having a just claim as aforesaid, as well as for the ....., and further, that the parties to the foregoing agreement may, from time to time, and as often as they see fit, make any additions to, ommissions from, or modifications of the work and the said agreement, which in the judgment of said parties do not materially increase the liability thereon, without consulting the Sureties hereto, and without in any way affecting their liability hereon.

WITNESS OUR SIGNATURES, this ..... day of ..... 19...

.....

Contractor

.....

Signed in the presence of:

.....

.....

.....

Surety

IN WITNESS WHEREOF, the said ....., of ...., has caused to be hereunto affixed its corporate name and seal by its ..... attested by its ...., and the said Contractor has hereunto set his hand and seal this ..... day of ..... A.D., 195...

.....

.....(Seal)

In Presence of:

.....

.....

.....

(Company Name)

.....

(Title)

By .....

(Title)

two finish coats, as light paints do not have as good hiding power as dark paints. The second coat should be darkened by the addition of lampblack, so that all areas may be successfully covered.

No finish coat should ever be applied over bare metal, especially when using aluminum paint, because a stain or yellowing by rust will show through within a few short months. Yet when aluminum is properly applied over a prime coat or over good patch coating, a highly satisfactory job is secured. The finish coat is more or less confined to the use of aluminum paint as about 95 per cent of all tanks and standpipes are now completed in aluminum. No particular skill is required for a dark or black graphite finish coat, except in being careful that brush marks are not noticeable. In using aluminum paint, every slight imperfection, every fault in workmanship, even irregular mixing, shows up glaringly. If only one coat is applied over old paint that has been patch coated with a rust inhibitive paint, the finish coat will have a somewhat mottled appearance, with some areas being slightly dull and other areas having high brilliance and luster. Generally, after about 60 days the aluminum paint will bleach to about the same appearance.

Cathodic Protection

During the past 10 or 15 years water works engineers and water works officials have given considerable study to corrosion losses in steel water structures and methods whereby it may be eliminated, or at least retarded. For this reason, substantial progress has been made in perfecting effective and economical protection to prevent internal corrosion in steel water structures by employing cathodic protection systems.

The theory of cathodic protection is relatively simple. The system consists primarily of a source of direct current, and necessary electrical wiring for connecting an anode system to provide adequate current density to maintain and distribute current to all parts of a steel structure that is in contact with water. The power unit or rectifier reduces and converts 110-volt alternating current to a more favorable direct current of 6 volts or more. The electric circuit is completed by using the steel structure as a conductor to return the current to the negative terminal of the rectifier. In operation, direct current flows from the rectifier into the anodes and then through the water to the metal surfaces of the tank.

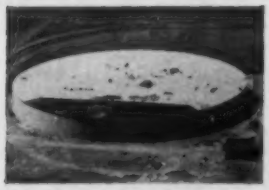
The value of cathodic protection depends entirely upon a correctly designed anode system. Anodes generally used in most water tanks are made from aluminum and magnesium, because this material is mechanically strong, with ample tendency to resist deterioration when current is flowing from its surface. It is also less expensive than other anode materials.

For a cathodic protection system to accomplish its purpose in a steel water tank, the anodes must be correctly positioned, and adequate in number, diameter and length to properly distribute current to all parts of the tank in contact with water. Due to these facts, when contemplating an installation it is advisable to consult reliable manufacturers with skilled engineers who will analyze each individual factor of the particular job requirements.

After a properly designed system has been in operation for several months, a white chalky film will form on the bare metal beneath the rust or corrosion. This chalky film, being mainly calcium carbonate from the water, turns the surface of the metal to clean gray steel. The coating gradually increases and retains the same appearance as long as the system is properly maintained. It also is advisable to employ a reliable company with trained and competent service crews for maintaining the system to assure efficient and dependable protection. This can be done on an annual basis for a nominal charge. These systems are being used quite extensively and have proven to be dependable. However, they must be of ample size, properly installed, and properly maintained to produce the desired results. They will ony protect the area of the tank interior where the water is in direct contact with the metal. They will not protect the area of the tank about the water line, or that area of or near the bottom that is usually covered by silt, debris and sand of varying depth, unless this is moved before installation of the system.

Summary

Whenever a utility or other tank owner feels that work is needed to properly repair or paint a water storage structure, complete knowledge should be gathered as to just what work needs to be done, what materials are to be used, the manner in which the work is to be performed, and the cost, before contracting with any firm for such work. The greatest security that a tank owner can have in the performance of such work is that comprehensive liability and workman's compensation insurance is carried on each contract. For the performance of the work demand a corporate bond, not an individual bond. Use care in selecting a contracting company. If an honest reliable contractor is selected, most of your duties and worries are over before the work is started.



PRELOAD PRESTRESSED CONCRETE TANKS

■ *Water tanks* ■ *Standpipes* ■ *Elevated tanks*
■ *Digestion tanks* ■ *Pressure vessels*

Prestressed concrete offers the following advantages:

- Economical first cost
- Maintenance costs 75% less than other types
- Architecturally pleasing
- 75% contract price is spent in the local community
- Standard, proven design

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THE PRELOAD COMPANY, INC.
211 East 37th Street, New York 16, New York

ENGINEERS IN PRESTRESSED DESIGN

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history of prestressed tanks

The history, development, use and acceptance of prestressed concrete tanks justify their consideration for any storage project.

Preload started designing and constructing prestressed concrete tanks in the mid 1930's. An early example of this work is the 50′ diameter x 100′ high 1.5 MG standpipe constructed for the City of New Britain. Constructed in 1936, it has required no maintenance and is still in constant service. In 1943, Preload introduced its wire winding methods which have been in successful use throughout the world ever since. This mechanical method of prestressing tanks is the only U. S. method of prestressing, including linear methods, which has been exported for extensive use in foreign countries under license agreements. Operations have been or are under way in Algeria, Australia, Canada, Cuba, Colombia, France, Great Britain, Italy, New Zealand, Peru, Union of South Africa, Uruguay and others.

Through 1947, some 470 tanks had been constructed to Preload designs totaling 166,000,000 gallons. This averages 350,000 gallons per tank. Since 1947 and through 1957, over 660 tanks have been constructed to Preload designs; these total one billion gallons and average 1,500,000 gallons per tank. This sharp rise and increase in use in the past decade strongly indicates the wide spread acceptance of this method of construction. These tanks have been built for ground and elevated water storage, water treatment, sewage digesters, petroleum storage and many other industrial applications.

In recent years, the use of prestressed concrete for larger and larger tanks has become evident. Last year saw the completion of 2—292′ diameter 13,000,000 gallon tanks for the City of Reading, Pa. Gilbert Associates Inc. were Consulting Engineers. 1958 will see the City of Springfield, Mass. advertise for bids for 2—15,000,000 gallon tanks, 320′ in diameter for addition to their Provin Mountain Reservoir. Bogert & Childs Associates are the overall consultants. The East Bay Municipal Utility District of Oakland, California, is now constructing a 10 MG tank. This Utility has nearly 40 prestressed concrete tanks in service.

In brief, Preload tanks are not something new, prestressing is not a fad, it's a tool to be used by the resourceful designer to help his client solve a storage problem.

what is a prestressed tank

A concrete tank is considered to be prestressed when it is designed and constructed so that when the tank is full, the ring forces created do not cause any circumferential tensile stress in the concrete. Since a prestressed concrete tank is designed as a cylindrical shell with edge restraint, vertical moments result when the tank is initially prestressed and moments of opposite sign but of less magnitude result when the tank is filled. These moments and the resulting tensile stresses and how they are reinforced for are probably the most important aspect of prestressed concrete tank design. A tank wall may be reinforced vertically by prestressed or mild steel reinforcement or a combination of both depending on the magnitude of the residual tensile stress. In any case of residual tension, mild steel reinforcement must be provided.

In a Preload type prestressed concrete tank, the uniformly stressed circumferential prestressing is so designed and placed that no circumferential tensile stresses are created when the tank is full. The Preload tank also provides a well balanced design for the vertical moments due to edge restraint, temperature differentials, backfill, etc., so that total bending tensile stresses are low.

In the above description of a prestressed concrete tank, you will note a strong emphasis on the matter of vertical bending stresses. We accept as axiomatic that no circumferential tension can occur in a wire wound Preload tank; therefore, the major emphasis in design is found in the problem of vertical bending.

Our current practice in designing tanks including full design criteria is described in detail in our Bulletin T-19, "Design of Preload Tanks," which is available on request. These criteria are accepted by agencies of the Federal Government, the Portland Cement Association and many municipalities.

Since 1953, Preload has been using a rubber pad at the base of the wall and under the dome ring of dome roofed tanks in order to reduce the edge restraint as much as possible. This feature has made possible very great improvement in Preload tanks. Dumbbell type rubber water stops are used between the footing and wall and in all floor and wall construction joints so that positive joint tightness is assured. With the rubber pad, on which the wall floats, the restraint is accurately determined from shear resistance data of the rubber furnished by the manufacturer. Vertical bending due to edge restraint is reduced to about 30% of that resulting from even the best of sliding joint preparations abandoned by Preload because of the uncertainty of field results. Owners should note carefully any proposed designs based on sliding base details as nearly 50% of the circumferential prestressing usually must be applied before static friction is overcome and sliding starts. Until sliding does start, the base must be considered as hinged and the vertical stresses analyzed accordingly. The rubber pad base joint contains patented features.

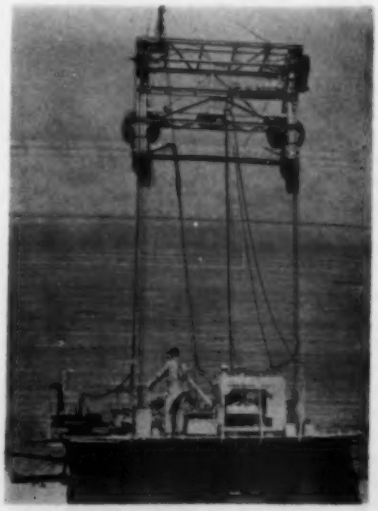
An example of the effect of edge restraint on the vertical stresses is shown in the table on the following page taken from Preload Bulletin T-19.

construction

The construction of the floor, core walls, and roofs of Preload tanks follows sound standard construction practice, and may be of concrete or pneumatically applied mortar depending on the size of the tank.

floors

Floors for Preload tanks may be of either 4″ poured concrete or 2″ pneumatic mortar. In each case ½% of reinforcement, each way, is provided. Pneumatic mortar floors normally do not have expansion joints. Poured concrete floors are usually subdivided for ease of pouring, but each construction expansion joint is sealed with a rubber water stop. For best results, floors should be kept moist or flooded with a thin layer of water until the tank is placed in service.



Preload heavy duty Merry-Go-Round wire winder, stressing .192 wire to 150,000 PSI initial stress. Two 13.0 MG reservoirs—292′ ID x 27′4″ SWD, Reading, Pennsylvania

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	RUBBER PAD BASE		SLIDING BASE COEF. OF FRICTION—.5	
TANK EMPTY	OUTSIDE FACE	INSIDE FACE	OUTSIDE FACE	INSIDE FACE
Dead Load	+ 61	+ 61	+ 61	+ 61
Base Restraint	+175	—175	+445	—445
Summation	+236	—114	+506	—384
Temperature	— 70	— 70	— 70	— 70
Summation	+166	—184*	+436	—454*
TANK FULL				
Dead Load	+ 61	+ 61	+ 61	+ 61
Base Restraint	+ 29	— 29	—335	+335
Summation	+ 90	+ 32	—274	+396
Temperature	—169	—169	—169	—169
Summation	— 79	—137	—443	+227

* For the same stresses for both designs provide (454 — 184) = 270 psi with vertical prestressing (32,500 #/ft. of wall).

3 MG . . . 133' ID x 29' SWD water tank, Montgomery County (Dayton) Ohio

walls

The walls for Preload tanks may be built of either concrete or pneumatic mortar. It is usually economical to use pneumatic mortar when the walls are less than 6 inches thick; concrete when they are thicker. In each case, the forms are designed and erected in accordance with standard construction practice. Cast-in-place concrete walls are usually constructed in segments of full height. Rubber water stops are used in all vertical joints. After the walls have been shot or poured, they are allowed to cure and reach a strength of at least 1.8 times the initial circumferential compressive stress before the circumferential prestressing is applied. Vertical reinforcement as required by the design may be prestressed or standard mild steel bars, or a combination of both. The prestressed reinforcement usually is comprised of high strength bars or wire cables similar to those used for prestressing bridge girders.

roof

Roof design for Preload concrete tanks may be dome, cast-in-place flat slab, precast flat slab or cable suspended; the choice being dependent upon the basic tank design or operating requirements.

The recommendations of the Joint Committees of Standard Specifications ACI-ASCE for Concrete, Reinforced Concrete and Pneumatic Mortar, form the basis of Preload construction specifications, practice and recommendations. Detailed Technical Specifications for the construction of Preload tanks are available on request.

the prestressing operation

A circular tank is prestressed by winding high strength wire around the concrete core wall with a self propelled machine riding on and around the wall of the tank. The wire is stressed by drawing it through a die of smaller diameter than the normal wire. This operation is similar to the wire drawing process used in the mills for making the wire. Accurate stress levels are obtained and the stress around the tank is uniform because there is no slippage of the wire on the tank wall after it is in place in its stressed condition. A stress measuring instrument is available on each job to check the wire stress on the tank.

After the circumferential reinforcement has been placed, a coating of pneumatic mortar is applied to the outside wall to bond the wire to the wall and provide permanent protection against corrosion. For complete protection, the exterior coat of pneumatic mortar need be no more than 5/8" thick. When the design of the tank calls for multiple layers of wire, each under layer is given a 1/8" protective coating. The pneumatic mortar also lends a highly attractive appearance to the finished structure and requires no maintenance.

Preload, its construction licensees or competent local general contractors, experienced in reinforced concrete work, can successfully and economically build Preload tanks. Where local general contractors are to perform the general concrete work, Preload or one of its licensees will serve as a sub-contractor for the specialized portions of the work. We have intentionally "designed out" troublesome construction details and simplified construction requirements. To assist the local consultant, or inspection group of the owner, Preload has an "Inspection Check List" which provides helpful hints. It is also an inspection guide to assist the contractor, by proper inspection, in meeting the intent of the plans and specifications. Preload can furnish a Field Engineer for special inspection duties if desired.

design and cost estimating

The Consulting Engineer or Owner normally determines the medium of design and construction for a structure. With tanks the choice is between steel, reinforced concrete and prestressed concrete. Advantages and disadvantages can be stated for each. Seldom does an Engineer design a reinforced concrete tank and also a steel tank for taking competitive bids on the same job. It is just as inconsistent to place prestressed concrete in competition with either reinforced concrete or steel. The three types are not comparable in life expectancy, fire resistance, serviceability, maintenance, availability, or initial cost.

The Engineer can easily make a reasonably accurate cost estimate for a reinforced concrete tank. Steel companies gladly give prices for steel tanks to which must be added cost of foundations, painting, and such corrosion control methods as cathodic protection or interior coatings, and evaluated costs of maintaining the steel tank during its life.

Accurate cost estimates for prestressed concrete tanks are easily obtained. On standard tanks Preload or its Licensees will furnish estimates accurate within 5% based on current labor and material costs. With the price for the structure accurately determined, the Engineer can make his evaluation and comparison with other

2 MG water tank . . . 160' tower, 195' to overflow, Tyler, Texas

For details circle 542 on inquiry card

Two 13.0 MG reservoirs—292' ID x 27'4" SWD, Reading, Pennsylvania

Two 2.0 MG reservoirs—83' ID x 40' High to be backfilled asymmetrically with fill sloping from 40' to 20' on the wall, Commonwealth Water Company, Summit, N. J.

methods of design and construction and decide on which to use.

Contract documents may be prepared in several ways:

(1) If a decision is made to use a Preload tank, Preload will be glad to cooperate with the Engineer in preparing engineering plans and specifications to be included with the contract documents for issuance for bids.

(2) In lieu of (1) above, or if alternative methods of construction are decided on, then Preload will cooperate with the Engineer in preparing definitive specifications including detailed design requirements to be incorporated with the contract documents. Bidding contractors should file copies of design calculations and drawings with their bids.

(3) In special cases of alternative bids, and after Preload has had an opportunity to review the proposed alternative methods, it may be suggested to the Engineer that engineering drawings for the prestressed concrete tank should be prepared and issued in the interest of the client. In such case, Preload will assist in the preparation of such plans as in (1) above.

In some cases, the Owner has elected to negotiate with Preload for the furnishing of the prestressing work for the project for a lump sum price that represents a small percentage of the cost of the complete tank. This price can be included in the contract documents with a stipulation to all bidding general contractors to include this sum as an allowance item in their bid. The general contractor will then engage Preload or one of its licensees as a sub-contractor for the specialized work. This procedure is particularly well suited to situations where only a Preload tank is desired.

Local material prices, labor rates and conditions will influence greatly the final bid price of a prestressed tank just as they do for any other construction. Since a Preload tank is constructed with formwork, concrete and reinforcing steel, over 75% of the contract price is spent in the local community for labor and materials. This should be an important point when steel tanks are being considered as the percentage of local expenditure is just about reversed.

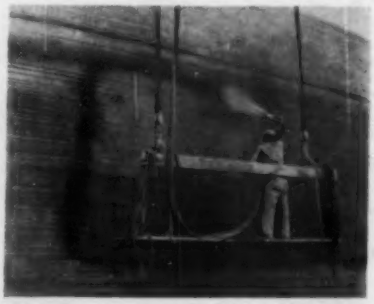
maintenance

Based on average U. S. conditions the larger capacity Preload tanks are generally more economical than conservatively designed reinforced concrete tanks. Smaller tanks may show no economy in initial cost but the advantages of prestressed design frequently justify the selection of a Preload tank. Preload tanks may cost slightly more in bare initial cost than ground storage steel tanks. However, steel elevated or underground tanks generally are more costly than comparable designs in prestressed concrete.

Since alternative methods may be considered, a complete economic evaluation must include the cost of maintaining the facility during the bond period of service life. In comparison with steel tanks, the cost of adequate regular maintenance becomes a substantial item of cost. Depending on local conditions, proper inspection, and maintenance, steel tanks will average 2.5¢ to 4¢ per square foot of maintained surface. This should include floor, interior and exterior surfaces of walls and roof. With column supported roofs the structural system involves a considerable area and should not be disregarded. It must be realized that prices will increase as they have in the past; therefore, the present maintenance dollar will have to be nearly doubled to represent the average cost for a 25 year period.

In summary, the Engineer and Owner should look on prestressing as another medium with which to build their storage tank, whether it be underground, surface or elevated. This is not a new material or concept; it is a recognized and accepted solution.

Wall will float on 5" x 12" x 2" rubber pads. Rubber water stops positively seal all construction and articulated joints.



Pneumatic mortar cover coating for wire protection.

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Rubber-Seated Butterfly Valves

Part 1—How to Select the Proper Size

by A. E. HATCH, Jr. and W. H. CHAMBERLAIN

Sales Engineer and Development Engineer, respectively, Builders-Providence, Inc., Division of B-I-F Industries, Inc., Providence, R. I.

DURING recent years, municipal and industrial water, sewage and waste treatment plants have been benefiting from the unique design features of rubber-seated, tight-closing butterfly valves. Among the basic characteristics contributing toward their wider acceptance and increased use on control and open-shut service are:

1. A uniformly changing coefficient of flow versus degree of opening.
2. Low head loss when in wide open position.
3. Bubble-tight shut-off.

The intent of this article is to aid potential users in selecting the proper size valve to provide optimum service for a particular installation. All data and formulas presented here are based on numerous tests conducted over many years, and apply specifically to butterfly valves *used with liquids*. This information is also applicable to gases and vapors if the pressure drop through the valve does not exceed approximately one-fourth the absolute pressure.

The curves included with this article are based on 90° seated butterfly valves.

Flow Control and Head Loss

In order to visualize the control characteristics of a butterfly valve, first consider the typical system shown in Fig. 1 and the head loss equation:

$$\Delta H_o = (C_p + f\frac{L}{D} + 1)\frac{V^2}{2g}$$

$$= (C_p + K)\frac{V^2}{2g} \qquad \text{Eq. 1}$$

(Note—the digit 1 in the above equation has been included to cover discharge loss which occurs in any system without a recovery cone at the point of discharge. Often this loss is negligible compared to pipe friction but when this equation is applied to very short pipe runs, the discharge loss plays a significant part in limiting the maximum velocity)

For the sake of convenience in applying Equation 1, the equivalent pipe friction and the discharge loss are combined into one system loss coefficient, K. The butterfly valve loss coefficient, C_p, is taken from Fig. 2 for any given disc angle.

Actual velocity and flow rate, with the valve in the system, can be calculated by using Equations 2 and 3 (developed directly from Equation 1):

$$V = \sqrt{\frac{2g\Delta H_o}{C_p + K}} \qquad \text{Eq. 2}$$

$$Q = 352.5\, D^2 \sqrt{\frac{2g\Delta H_o}{C_p + K}} \qquad \text{Eq. 3}$$

The flow control characteristics for a butterfly valve can be presented in the form of a set of curves (see Fig. 3) where

$$\frac{100 \times Q}{Q_{max}}$$

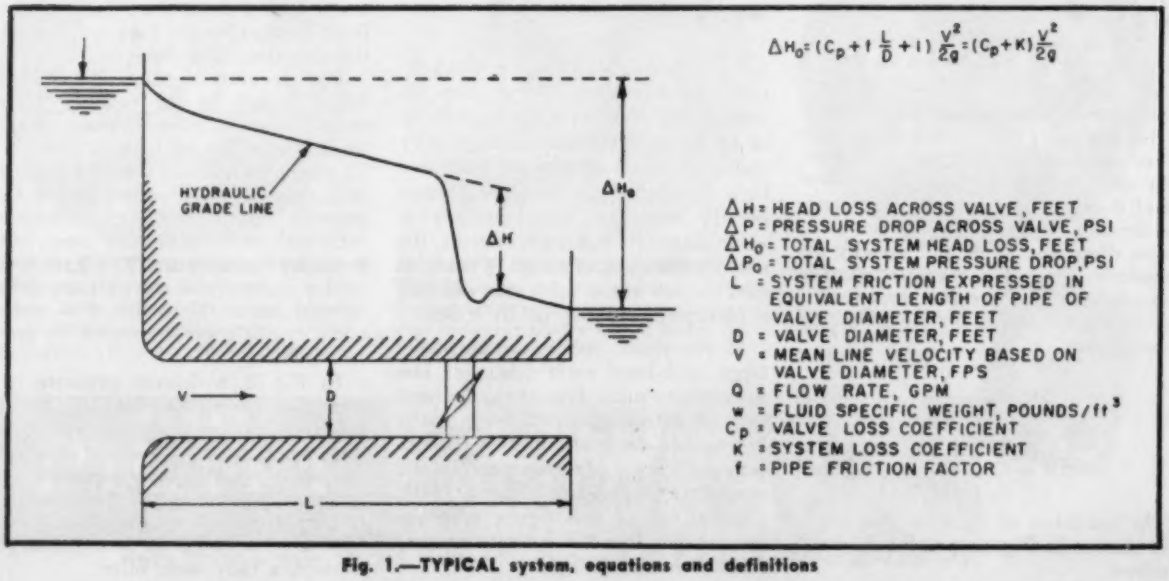

$\Delta H_o = (C_p + f\frac{L}{D} + 1)\frac{V^2}{2g} = (C_p + K)\frac{V^2}{2g}$
HYDRAULIC GRADE LINE
ΔH_o
ΔH
V
D
L
ΔH = HEAD LOSS ACROSS VALVE, FEET
ΔP = PRESSURE DROP ACROSS VALVE, PSI
ΔH_o = TOTAL SYSTEM HEAD LOSS, FEET
ΔP_o = TOTAL SYSTEM PRESSURE DROP, PSI
L = SYSTEM FRICTION EXPRESSED IN EQUIVALENT LENGTH OF PIPE OF VALVE DIAMETER, FEET
D = VALVE DIAMETER, FEET
V = MEAN LINE VELOCITY BASED ON VALVE DIAMETER, FPS
Q = FLOW RATE, GPM
w = FLUID SPECIFIC WEIGHT, POUNDS/ft^3
C_p = VALVE LOSS COEFFICIENT
K = SYSTEM LOSS COEFFICIENT
f = PIPE FRICTION FACTOR

Fig. 1.—TYPICAL system, equations and definitions

is plotted against α:

Where

Q is the flow rate for the valve position.

Q_{max} is the flow rate for the valve fully open.

α is the angular position of the vane measured from the closed position.

The curves show, for various values of K, the percent of maximum flow rate that is achieved at each valve angle. Note that although Q varies with the system supply pressure (for a given angle of opening), the ratio Q/Q_{max} does not.

The curves in Fig. 3 also can be used where the valve diameter is less than the line diameter; however, in this event the coefficient K must be computed as:

$$K = \frac{(\text{Valve diameter})^4}{(\text{Lime diameter})^4} K_{line}, \quad \text{Eq. 4}$$

Where K_{line} is the coefficient for the system in which valve and line diameters are the same. Note, for example, that reduction of the valve size to about 7/10 line diameter reduces the coefficient K to one-fourth its original value.

Selecting Proper Valve Size

For a fluid with a specific gravity of 1.0, the relations between pressure drop, disc angle, velocity, valve size and flow rate are given in the nomograph, Fig. 4. This nomograph can be used for other fluids with a specific gravity other than 1 by multiplying the "as read" pressure by the specific gravity of the fluid.

An example of the use of the nomograph is shown by the dotted line. Note that two separate relations are shown, with velocity as the common variable. The relation between flow rate, valve diameter and velocity expresses the continuity of flow and does not depend on valve characteristics. The relation between pressure drop, disc angle and velocity introduces the valve characteristics in the form of the pressure loss coefficient Cp, as shown in the following equations:

$$\Delta H = C_p \frac{V^2}{2g} \quad \text{Eq. 5}$$

$$\Delta P = C_p \frac{W V^2}{(144)2g} \quad \text{Eq. 6}$$

The variation of C_p with disc angle is shown in Fig. 2, previously mentioned.

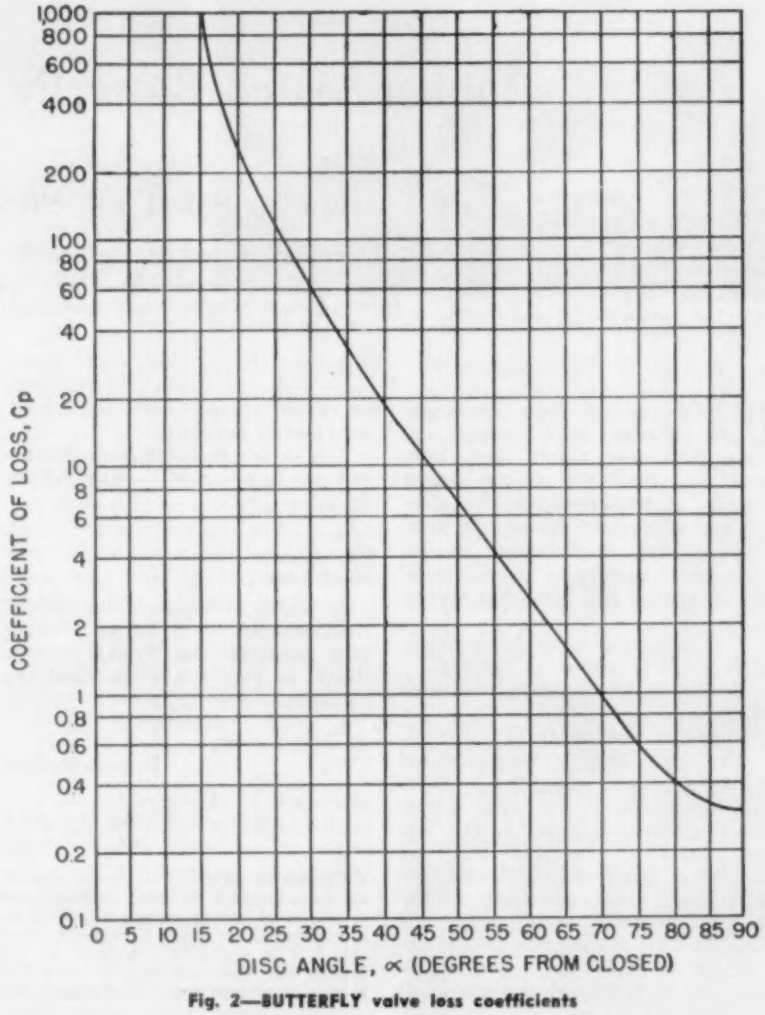


Fig. 2—BUTTERFLY valve loss coefficients

Rules of Thumb For Valve Size Selection For Control

1. In choosing a valve for best control characteristics, select the diameter that gives a maximum velocity of 16 ft/sec. when the valve is fully open. For systems with relatively high friction, Q_{max} does not change greatly even for large changes in valve diameter. For such systems, the nomograph (Fig. 4) can be used to find the size of the valve that will give a maximum velocity of 16 ft/sec.

If the result means an unusually large neckdown ratio (ratio of line diameter to valve diameter), the head loss for a wide-open valve can easily be checked by continuing to the upper portion of the nomograph and reading the pressure drop at 90°. Comparison of this figure with the total system loss will indicate whether the losses are too high.

2. Start with a valve loss at maximum flow of about ten percent of the fixed system losses, then work from there to the valve diameter.

For accurate results, the added losses caused by the reducers in a necked-down valve installation should be accounted for by using a value of C_p somewhat greater than 0.3 for the fully open valve. This increase in C_p depends upon both the neckdown ratio and the reducer cone taper, but in normal installations it will not exceed a valve of 1.0 even for abruptly tapered cones. Normally, this resistance is negligible compared to system friction.

In Fig. 1, a definite pressure recovery is shown to result from the velocity issuing from the valve. If the pipe downstream of the valve is too short or otherwise arranged so that it does not flow full, this recovery of pressure will not occur and C_p will have a valve of 1.0 for free discharge through a fully open valve.

these are the features

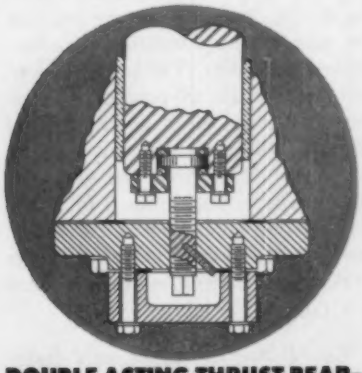
POSITIVE, MECHANICAL RETENTION makes rubber seat truly field replaceable. No dependence on glues, cements or vulcanizing . . . no chance for liner "blow out."

90° SEATING . . . wiping action as disc closes makes valve self-cleaning. "Cork-in-bottle" closure requires no operator force to keep valve closed.

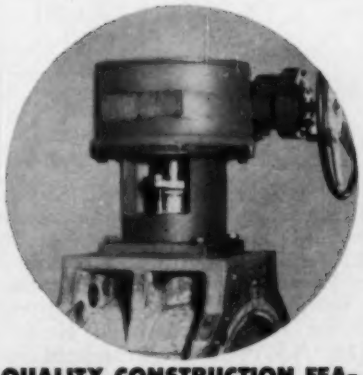
HAND POLISHED DISC EDGE eases entry of disc into rubber seat for minimum wear and permanent tightness. Accurate disc machining assures *uniform* interference.

that make PRATT VALVES

CONSERVATIVE DESIGN of entire valve, typified by rugged internal ribs in this fabricated disc—tubular shaft housing to prevent disc flooding.



DOUBLE ACTING THRUST BEARING supplied on every valve, positively holds disc in center of rubber seat. Oversize bearing surfaces prevent wear—ensure continued alignment.



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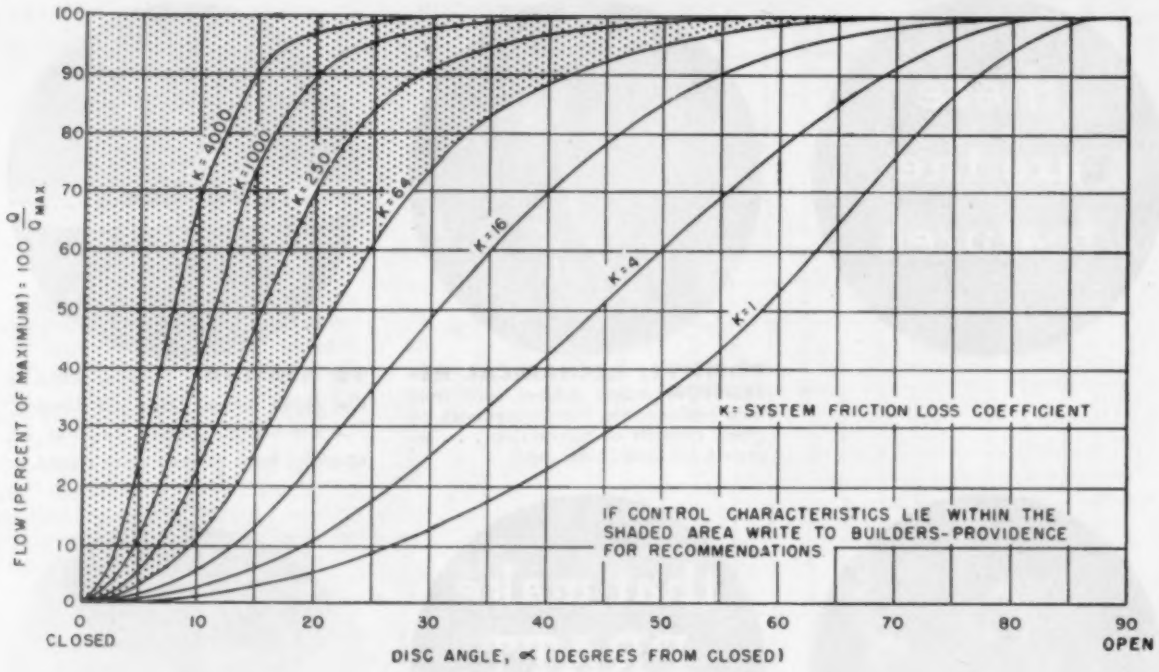
FLOW (PERCENT OF MAXIMUM) = 100 Q/Q MAX
DISC ANGLE, ∝ (DEGREES FROM CLOSED)
CLOSED
OPEN
K = 4000
K = 1000
K = 250
K = 64
K = 16
K = 4
K = 1
K = SYSTEM FRICTION LOSS COEFFICIENT
IF CONTROL CHARACTERISTICS LIE WITHIN THE SHADED AREA WRITE TO BUILDERS-PROVIDENCE FOR RECOMMENDATIONS

Fig. 3—BUTTERFLY valve control characteristics

Note: This value of 1.0 is in addition to the value of 1.0 already introduced to account for pipe discharge loss.

Sample Problem of Selecting Valve Size

For this example, we will select a problem typical of the water treatment plant influent basin level control when supplied by gravity from a reservoir several miles away. Assume that the reservoir level is 62 feet above the influent basin and the supply line is a 36 in. pipe 7 miles long, with a friction factor of .02. In addition, there are several elbows in the line giving it an equivalent length of 7.1 miles. Since there is no recovery cone at the point of discharge,

$$K = f\frac{L}{D} + 1$$

$$= .02\,\frac{(5280 \times 7.1)}{(3)} + 1$$

$$= 251 \text{ Eq. } 7$$

This result, of course, is based on a line size valve. The control characteristic is shown in Fig. 3 by the K=250 line. Note that 95 percent of maximum capacity is obtained at 35° open and if the line was designed for a good margin of growth, it will operate in the 0 to 15° open region during its first years of use. Note the maximum velocity obtained with wide open valve (per Equation 2) is:

$$V_{MAX} = \sqrt{\frac{2g\Delta H_o}{C_p + K}} = \sqrt{\frac{2 \times 32.2 \times 62}{.3 + 251}}$$

$$= \sqrt{15.9} = 3.98 \text{ fps}$$

and from Equation 3

$$Q_{MAX} = 352.5\ D^2V$$

$$= 352.5\ (3)^2\ 3.98 = 12{,}620 \text{ gpm}$$

By using a valve of half the line diameter, we obtain approximately four (4) times the velocity, or 16 ft./ sec. This is calculated according to Equation 2, using C_p=1.3 to account for the extra loss of relatively abrupt reducer cones and K=250 $(18)^4/(36)^4$ = 15.7 corrected for valve size, according to Eq. 4.

Substituting this K value of 15.7 in Eq. 2, we obtain

$$V_{MAX} = \sqrt{\frac{2 \times 32.2 \times 62}{1.3 + 15.7}}$$

$$= \sqrt{235} = 15.3 \text{ fps}$$

and from Eq. 3

$$Q_{MAX} = 352.5(1.5)^2\ 15.3$$

$$= 12{,}280 \text{ gpm}$$

Then line velocity is 15.3÷4= 3.82 or 96 percent of its previous valve. It is clear to see that in problems of this type, the extra loss due to neck-down valve size has minor effect on maximum capacity. Looking at Fig. 3 for K=16, we see that the control characteristics have improved materially. The probable control range of 0 to 50 percent of maximum, allowing for a good marginal growth, will now use valve angles up to 30°. Note that the very low flow characteristics from 0 to 5 percent are now spread over a 10° range, enabling a standard valve positioner to do a good control job even at these low flows.

Establishing 16 ft./sec. as a design rule is a convenient way of limiting the effect on line capacity to reasonable values, and still adhere to the operating conditions established by AWWA to keep operating torque and cavitation effects within bounds.

In general, the best control valve is the smallest control valve consistent with required line capacity and allowable velocity through the valve.

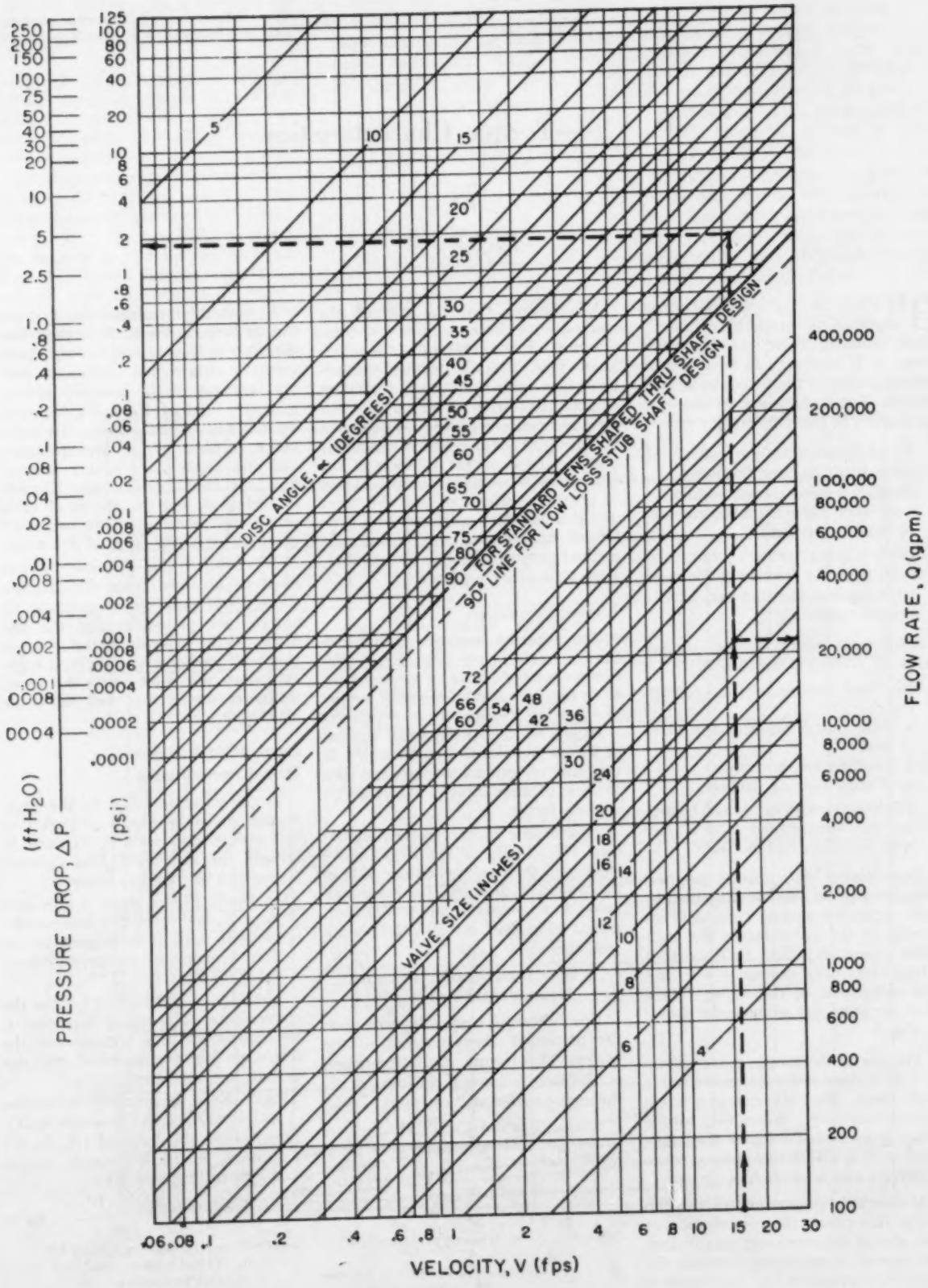

Fig. 4—BUTTERFLY valve sizing nomograph

Part 2—Torque Characteristics

BEFORE the *total operating torque* required to properly operate a given butterfly valve can be determined, it is necessary to have a clear understanding of the forces to be considered. Total operating torque is a summation of the following:

1. Fluid-dynamic torque—which always tends to close the valve.
2. Bearing friction torque—which occurs when valve is moved and acts to oppose rotation.
3. Seat friction torque—which results from the friction of the valve edge against the seat and acts to oppose rotation.

Additional minor torque components are present in the form of:

4. Residual friction torque—consisting of:
   a. Disc hub friction at the valve seat.
   b. Stuffing box friction.
   c. Thrust bearing friction.
5. Hydrostatic torque—which is present only when closed valve is filled with liquid *on just one side.*

Determining the torque requirements of a given valve is simplified by these facts: the seating friction drops rapidly as the valve leaves the fully closed position; the fluid-dynamic torque rises very gradually with this first movement of the valve. These characteristics are graphically shown in Fig. 6.

The use of the torque curve shown in Fig. 5 does not require the valve angle lines. They serve to give extra information only. When this torque curve is presented without the angle lines, it is a single line torque curve showing C_t as a function of the angle.

It should be pointed out that in the use of this curve, the computation of the value of the maximum torque does not depend on accurately locating the point of tangency on Fig. 5, but rather on the point at which the tangent line intercepts the vertical axis.

We believe that the use of the method noted here requires less computation effort to determine the maximum fluid-dynamic torque encountered by a valve in a system, than does computation with other single line torque coefficient curves. Actually, it is difficult to compare the two methods because the complete solution of the older method requires a graphical plot of several solutions to find the point of maximum torque. It may be a matter of opinion but we believe the method proposed here is less cumbersome than other methods.

Torque Components

The required operating torque can thus be found as *the sum of seat friction torque and bearing friction torque,* or as *the sum of fluid-dynamic torque and bearing friction torque,* whichever is larger. An additional small amount of torque should always be added to take care of residual torques, and then the sum of these torques multiplied by a safety factor.

Hydrostatic torque reaches significant values only in the larger valve sizes, and then only when one side of the valve is drained. Its maximum value, in a horizontal line with a horizontal valve shaft, is $0.59\ WD^4$ pound-feet where:

W = fluid density (lb/cu ft)
D = valve diameter (ft)

Fluid-dynamic torque depends upon the particular characteristics of the system. This torque may be expressed in the two following equations . . . through dimensional analysis:

$$T = 62.4\ C_t\ D^3 \Delta H \qquad \text{Eq. 8}$$

where ΔH = valve pressure drop (ft of water) and

$$T = C_d\ D^3 \frac{W\ V^2}{2g} \qquad \text{Eq. 9}$$

where $\frac{W\ V^2}{2g}$ = dynamic pressure (psf)

C_t = torque coefficient for use with pressure drop

C_d = torque coefficient for use with dynamic pressure

In both these expressions, T is the torque in pound-feet; D is the valve diameter in feet; C_d and C_t are experimentally determined coefficients and are functions of the complete system geometry and of Reynolds Number. Included in system geometry are valve shape, adjacent piping arrangements, and disc angle. At ordinary rates of flow, the effect of Reynolds Number is negligible, and the effects of valve shape and adjacent piping are small compared with the effect of disc angle.

Maximum fluid-dynamic torque must be obtained from the diagram (Fig. 5) because when coefficient C_t and C_d are plotted against the disc angle, α, the unfortunate fact emerges that both coefficients attain their highest values at a point where the actual torque encountered is well below the maximum.

Determining Maximum Fluid-dynamic Torque

For a valve installed in the basic system shown in Fig. 1 of Part 1 of this article, and with ΔH_o and K known, the *maximum fluid-dynamic torque* can be found as follows:

Step 1—In Fig. 5, draw a line with slope-K, and move this line parallel to itself until it is tangent to the fluid-dynamic torque curve (Example is for K = 16).

Note: As stated in Part I, "For the convenience of applying Equation 1, the equivalent pipe friction and the discharge loss are combined into one system loss coefficient, K."

Step 2—Read the intercept of this line with the $1/C_t$ axis (Example is 53).

Step 3—Use this value of $1/C_t$ in the formula for fluid-dynamic torque shown in Equation 10.

$$T_{max} = \frac{W \Delta H_o D^3}{1/C_t} \qquad \text{Eq. 10}$$

where W = fluid density (lb/cu ft)
ΔH_o = total system head loss (ft)
D = valve diameter (ft)
C_t = a function of system geometry and Reynolds Number as previously defined.

If valve diameter (D) is less than line diameter, correct K by means of formula shown in Equation 4 in Part 1 of this article.

Now if these expressions are applied to the example given in Part 1 of this article, we have an example solution to the problem of Fluid-Dynamic Torque Evaluation:

Consider two installations in which $\Delta H_o = 62$ ft. In one case $K = 251$ and in the other case $K = 15.7$. In the case for $K = 251$, you will note that a line tangent to the torque curve at slope 251 would intersect the $1/C_t$ axis off scale. This means the maximum fluid-dynamic torque is so low as to be inconsequential. However, the point of intersection can be established and in this case $1/C_t = 376$. For the case in which $K = 15.7$, $1/C_t = 52$.

Now solving for the fluid-dynamic torque in each case:

For the 36-in. valve:

$$T_{max} = \frac{W \Delta H_o D^3}{1/C_t}$$

$$= \frac{62.4 \text{ lb/ft}^3 \times 62 \text{ ft} \times (3 \text{ ft})^3}{376}$$

$$= 278 \text{ lb-ft}$$

For the 18-in. valve:

$$T_{max} = \frac{W \Delta H_o D^3}{1/C_t}$$

$$= \frac{62.4 \text{ lb/ft}^3 \times 62 \text{ ft} \times (1.5 \text{ ft})^3}{52}$$

$$= 251 \text{ lb-ft}$$

It must be remembered that in sizing a butterfly valve operator . . . valve bearing friction torque, valve seating torque, and a safety factor must be taken into consideration in addition to fluid-dynamic torque.

In this article we have purposely avoided computing on torques other than the fluid-dynamic torque as they vary with each design. For example, the 90 deg. seating valve has torques much different from the angle seating type. In addition, manufacturers undoubtedly use different bearing loadings and safety factors.

To avoid these lengthy calculations on water works valves, we recommend that the torque values in

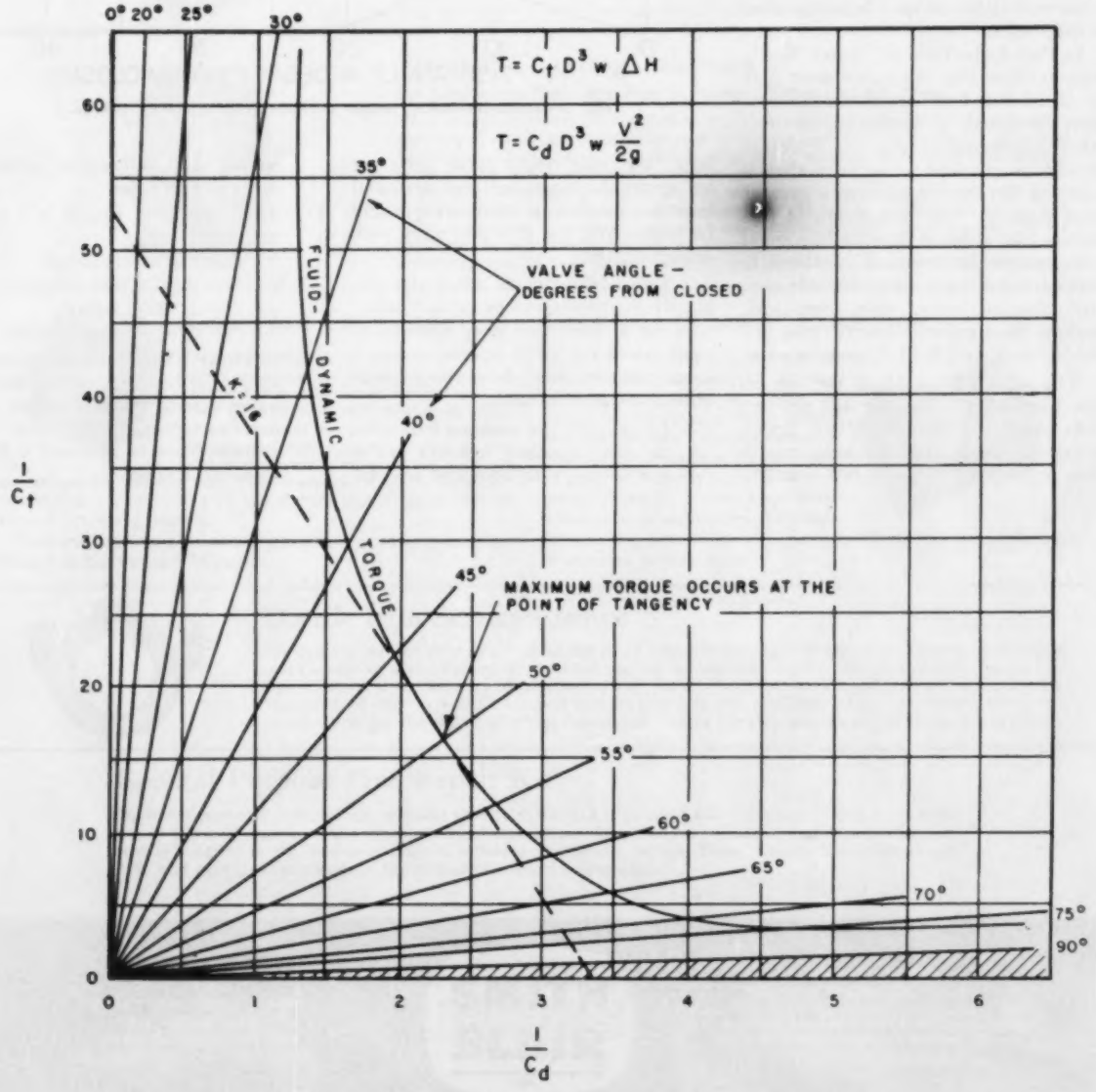

Fig. 5—TORQUE CHARACTERISTICS of rubber seated 90 deg. butterfly valves.

AWWA Specifications C-504-55T be used to determine safe values of operator torque. When conditions indicate possible reductions in operator size with consequent lower costs, valve manufacturers are glad to perform these calculations.

Summary (Parts I and II)

A) Basic Rubber-Seated Butterfly Valve Characteristics:
   1) A uniformly changing coefficient of flow vs. degree of opening.
   2) Low head loss when in wide open position.
   3) Bubble-tight shut-off.

B) Rule of Thumb for Size Selection for Control:

Choose a valve that gives a maximum velocity of 16 fps when the valve is fully open.

In Part I, the Rule of Thumb No. 1, says in effect that the valve must first be sized for flow requirements and then corrected, if necessary, to meet other requirements, e.g. the selection should be checked to be sure that it will not produce flow losses greater than desired. The advantage of this rule is that it leads directly to a good compromise between all of the size influencing criteria which include control characteristics, wide open loss, energy dissipation, velocity past the rubber seat, and fluid dynamic torque.

The selection of 16 ft per sec as the particular value to use on this rule was based on the AWWA Specifications which limit line velocities to this value. If it were not for this limit, the rule might have been set for about 20 ft per sec and a special limit for protecting valve seats would be higher yet, but it would vary with design details.

(Note: This rule is not given primarily for protection of rubber seats; it is for a quick and easy solution of most problems. For special cases, a more complete analysis of the problem should always be made.)

C) In general, the *best* control valve is the smallest control valve consistent with required line capacity and allowable velocity through the valve.

D) Total operating torque is a summation of:
   1) Fluid-dynamic torque.
   2) Bearing friction torque.
   3) Seat friction torque.
   4) Additional minor torques.

E) In sizing a butterfly valve operator, valve bearing friction torque, valve seating friction torque, and a safety factor must be taken into consideration in addition to fluid-dynamic torque.

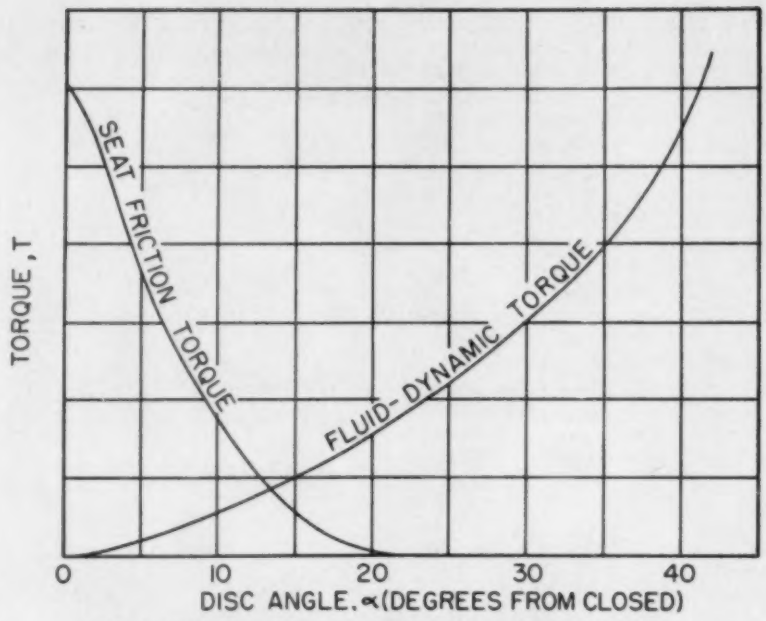

Fig. 6—FLUID-DYNAMIC torque coefficients of butterfly valves.

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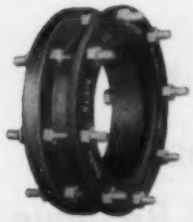

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"Cut-In" couplings are installed in half sections to minimize cut-out lengths when bells, couplings, or flanges are broken, or when breaks occur in the line. This unit takes the place of two couplings and a length of pipe, and allows pipe to be connected in place . . . even when it has a deflection of six degrees. Available for nominal pipe sizes of 2 through 12 inches; steel, cast-iron, or asbestos cement pipe.

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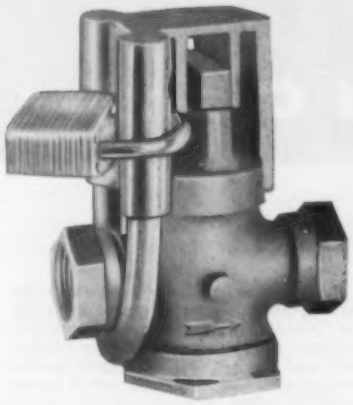

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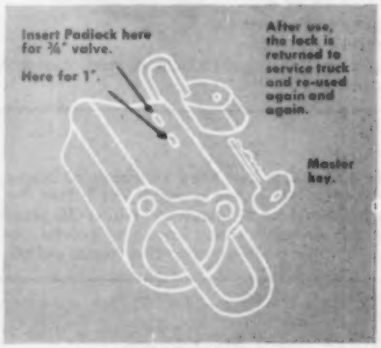
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How to Determine When Water Meters Need Repair and Replacement

by RICHARD V. FORD

Vice President of the Ford Meter Box Co.

A WATER WORKS MANAGER or superintendant faces a constant quandary in his meter maintenance program. If he keeps his meters in service until they stop, he is fairly sure he has lost income; if his removal tests show that his meters are sensitive and accurate, he is fairly sure that his meter maintenance program is costing too much.

What he wants is the largest *net* income, that is, total billings less the cost of his meter maintenance work. We can word the basic rule as follows:

"In any period of time, the highest net revenue from a metered water system is received when the cost of meter repair and maintenance just equals the loss of revenue if such work is not done."

As we use them, the words "highest net revenue" mean the total collections less meter maintenance and repair. "Period of time" is any period of years, usually from five to fifteen, during which all meters have been to the shop at least once. The cost of meter repair and maintenance is that cost of removal, replacement, repair and test necessary to bring the meter to a good operating state of efficiency. It should include transportation, supplies and repair parts. There may come a time when repairs cost more than replacements. In the overall picture, replacement must be included in "Cost of Metering".

Three Variables

So here we have three variables all affecting the answer to the question "How do we set up a water meter repair program?" From place to place the revenue from meters vary widely, due to rates and sewage surcharge. The cost of meter work varies. The rate at which meters lose accuracy depends largely on the water quality.

Now we have three factors which vary from city to city. Before we apply the rule, we must get the basic data. The three variables are:

1. Meter rates
2. Cost of meter work
3. Wear-out rate of the meter.

According to "Water Supply Statistics of American Municipalities," which lists water meter rates of 3500 water purveyors, water is sold as low as two cents per thousand gallons and as high as $3.25. These are extreme figures but variations from thirty cents to one dollar are common.

A Recent Complication in Meter Rates

Further complicating the meter rate is a factor new in the last few years—charging sewer rates as a percentage of water billing. As municipalities discover the high cost of sewage disposal, they have turned to the fairest way of charging for that service; the basis of use. This surcharge on the water rate is as high as 125 percent of the water billing. No good compilation of such surcharges is available as this is written, but it is logical to assume that the higher surcharges would be on the lower range of water rates, and the lower surcharges are in the plants with higher water rates.

For instance, a 100 percent sewerage surcharge on a 40-cent water rate would return as much as a 50 percent surcharge on an 80-cent water rate, if water consumption were the same.

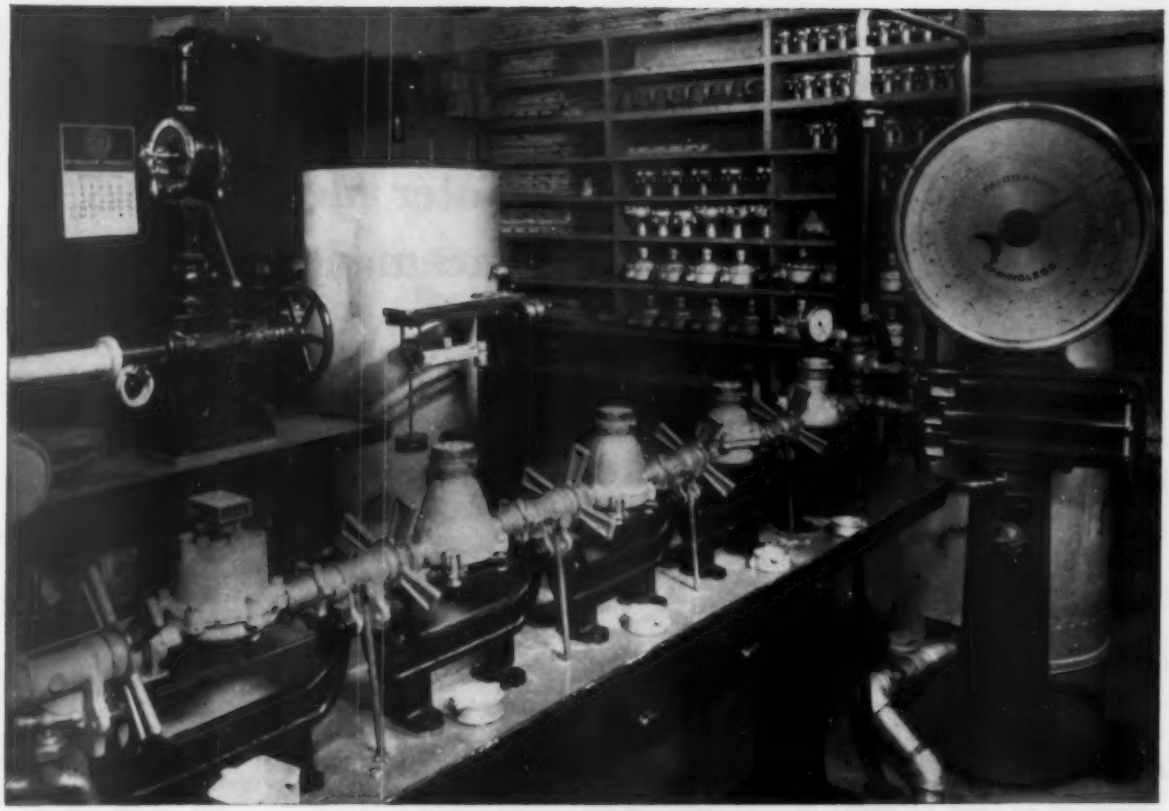
For the purpose of this discussion, it is assumed that these sewer rates, added as a surcharge, can affect total billings, up to 50 percent, depending on water meter readings. Applying that factor to water rate variations of 30 cents to one dollar per thousand gallons gives us a ratio of 1:5, from a 30-cent water rate with no sewer surcharge to a dollar rate with a 50 percent sewerage surcharge.

Thus we see that 1:5 ratio in rates is possible from one municipality to another.

Second and Third Variable

The second variation is the actual cost of meter work which varies over a wide range. Depending on many factors this cost may be of a 1:2 ratio. Quantity of work, cost of labor and transportation, operating efficiency,—even bookkeeping,—all vary.

The third variable is the wear-out rate of the meter itself. This is due



METER test bench at Little Rock, Ark.

mostly to the chemical and physical qualities of the water. In some waters a soft gelatinous coating soon covers and lubricates the disk and chamber, protecting them from wear. In other waters pitting and corrosion is common. This wear-out ratio from one community to another can be as high as 2:1, depending on the water quality.

Little wonder then that no universal figures can apply when the three variables range over so wide a spectrum. Because these three factors are unique for each water system, the meter program for each city should vary. Some states have meter replacement regulations which must be followed—at least by privately owned water companies. The replacement program described here is not to be used to replace such rules, but to supplement them.

An Example

Let us next talk about a particular water system and see how we can apply the general rule to it. Here the rates are known,—that removes one variable. The cost of meter repair and maintenance may be known if you are already doing such work. If you are not already doing this, we suggest that you start with a figure of $8.50 for a ⅝ inch meter. The reason for that figure being used is that good commercial repair work can be had for $7.50, and $1.00 is added for the cost of removal and replacement. As your cost data builds up you will have a more accurate figure to use.

The third and last unknown quantity to the equation must be obtained by experiment. This unknown is best expressed by the question, "How much have the meters slowed down?" A careful bench test, for instance, will show that a specific meter will not register at the ¼ gpm rate, or that the 2 gallon test rate shows only a 94 percent registration. But it is impossible to relate these test data quantitatively to revenue loss, except in the special case of a stopped meter.

Four Steps to Take

The only way we know of to find this answer is to use the series system of comparison. It is not a perfect way, but it will provide usable data. Here are the steps in getting the data:

1. Choose ten typical accounts from your meter books. Your records will show their past consumption and how long these meters have been in place without maintenance work. Choose ten that have been in service the same number of years, preferably meters that were new at the beginning of the period. Eight years is a good period to use, although any number of years from five to ten will do.

In selecting these ten meters try to get an average sampling of your entire list of customers, from the one who uses barely the minimum volume to the one who uses two or three times the average. The average recorded water use of these accounts should be close to the average of the entire system. Avoid erratic accounts. These ten accounts should represent a fair sampling of the entire system, so they should be carefully chosen.

2. Test and select ten test meters. These should preferably be new meters and should be tested accurately, particularly to determine their sensitivity to low flows. You should be able to find ten meters which will register over 95 percent

METER testing shop with multiple test bench at Louisville, Ky.

at ¼ gpm. These ten meters should represent the best possible metering.

3. Install these ten meters in series with the ten service meters chosen from your meter books. Special fittings (Fig. 1, and Fig. 2) are available for facilitating such double meter installations in various types of settings but are not essential. Any means of connecting the two meters in series into the service will serve the purpose.

4. After the series installations are made, read the test meters and the service meters and record the figures. Read again in 30 days, also in 60 days if you wish to have additional data. Or the test installations could be shifted to ten additional services if desired. All the figures should be assembled on a sheet of paper and calculations made from these data.

Examine the Data

Table 1 is a typical data sheet made up from actual test data. The values in the right hand column are the percentage accuracies of the service meters as compared with the test meters. You will probably find that the individual accuracies of your service meters will vary rather widely, as they do in this example.

The reason for variations is best explained by the statement that some of the accounts had small leaks or drips which were recorded on the sensitive new meter but not on the worn one.

TABLE 1
Test Data on Series of Ten Meters

1	2	3	4	5	6	7	8	9	10	11	12
Location of Meter or Account Number	Average Monthly Use (from meter book)	Make and Number of Meter	Age of Meter	Service Meter Reading At Start of Test	Service Meter Reading At End of Test	Water Registered By Service Meter	Test Meter Reading At Start of Test	Test Meter Reading At End of Test	Water Registered By Test Meter	Number of Gallons Lost by Service Meter (10-7)	Accuracy of Service Meter (7 divided by 10)
361	5050	X123456	8	485100	489250	4150	90	4420	4330	180	96%
892	5150	Y975346	8	494050	499750	5700	120	6370	6250	550	91%
1208	5150	Z975645	8	496840	502040	5200	80	6220	6140	940	85%
1191	4800	Z675640	8	460190	467140	6950	80	7330	7250	300	96%
480	7500	Y407821	8	715810	722690	6880	140	7740	7600	720	90%
1033	5000	X211891	8	478660	485910	7250	120	7870	7750	500	94%
1129	3120	X4185317	8	300820	303010	2190	160	2510	2350	160	93%
118	5400	Z988802	8	518850	525450	6600	140	7610	7470	870	89%
384	1390	X850017	8	133430	135460	2030	160	2230	2070	40	98%
214	690	X3171456	8	65670	66440	770	150	960	810	40	95%

NEPTUNE METER COMPANY

MAIN OFFICE: 19 West 50th Street, New York 20, N. Y. • FACTORY: 22-42 Jackson Ave., Long Island City 1, N. Y.

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NEPTUNE METERS, LTD. Main Office and Factory: 1430 LAKESHORE ROAD, TORONTO 14, ONTARIO
Offices: Calgary, Halifax, Montreal, St. John, Vancouver, Winnipeg.

TRIDENT WATER METERS

. . . Job Tested Ten Million Times

For over 50 years, more Trident meters have been purchased than any other make. Most of these . . . even the oldest . . . are still running accurately. This long serviceable life means lower amortization, obsolescence and replacement costs.

Trident meters have long led the field in design improvements, and today are the finest, most modern meters available. Every improvement has been made to fit all older Tridents. This is one of Trident's biggest advantages.

A planned schedule of testing and repair with Trident meters gives you a continuous program of meter modernization . . . at far less cost than scrap-and-replace methods. Repairs take less time, too, aided by Trident's extreme simplicity. A moderate stock of only the *latest* parts services *all* your Tridents. You waste no time searching or waiting for parts for old meters. Trident parts are *always* available. Your repair men have no obsolete models to learn. If they can repair one Trident, they can repair all . . . efficiently, economically.

TRIDENT METERS FOR DOMESTIC SERVICES IN COLD OR WARM CLIMATES

Trident meters combine fine-instrument construction with the inherent high accuracy achieved only in disc-type, positive displacement water meters. Accurate at all rates of flow within normal test flow limits and remarkably sensitive to small flows.

Trident Frost-Proof Meter embodies the original frost-proof meter feature. If the water freezes and expands, the cast iron bottom cap breaks, relieving the working parts from strain. The bottom cap can be replaced at very nominal cost. For warm climates, the Trident Split-Case Meter is recommended.

Among exclusive features for long accurate life are: Gear train is fully oil-enclosed, including the stuffing box, to isolate vital parts from abrasives, turbulence, corrosive elements, and to provide permanent lubrication. Anti-friction thrust roller absorbs disc thrust, making the Trident virtually immune to disc breakage. Heat-proof, hard rubber bushings in gear train and register are interchangeable. Sand ring keeps abrasive material out of working parts. Materials are corrosion-resistant, with special materials for unusual corrosion problems.

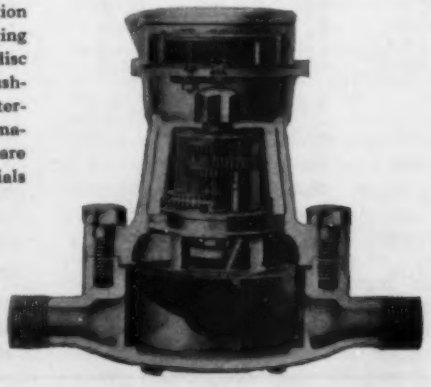
Easy to service and repair . . . makes big savings in meter costs over the years. Register has no screws. Chamber is snap-joint. Disc is in three parts, easy to adjust. Guide pins, slots, etc., assist in assembling meter properly.

Trident Frost-Proof Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
⅝	10¾	7½	5½	9	1¾	20
⅝ x ¾	11½	7½	5½	9	1¾	20
¾	15	9	6	9	1¾	30
1	26	10¾	9⅝	9¾	2	50
1 x 1¼	26	10¾	9⅝	9¾	2	50

Trident Split-Case Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
⅝	9	7½	5	8	1	20
⅝ x ¾	9½	7½	5	8	1	20
¾	12	9	5⅝	8⅝	1¼	30
1	20	10¾	7½	9	1⅝	50
1 x 1¼	20	10¾	7½	9	1⅝	50



For details circle 547 on inquiry card

NEPTUNE METER COMPANY

STYLE 3 TRIDENTS FOR MEDIUM RATES OF FLOW

A disc-piston meter for commercial and other installations requiring medium rates of flow larger than household consumption, but not great volumes. Also excellent for "battery" settings where preferred for metering wide flow ranges. In addition to sensitivity on low flows inherent in disc meters, it has the Trident oil-enclosed gear train, heat-proof removable bushings in register and gear train, interchangeable parts and other Trident features which give it sustained accuracy and low maintenance cost. On 1½" and 2" sizes, a "delivery adjustment" can be regulated in relation to line pressure to prevent racing.

These two sizes of Style 3 Meters do the work of any compound meter of equivalent size and, being simpler, they do it with less cost for maintenance and repair.

Trident Style 3 Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	36	12⅜	10	10⅝	2⅜	100
1½ Flge.	40	13	10	10⅞	2⅝	100
2 Scr.	58	15¼	12 1/16	11¾	3¼	160
2 Flge.	61	17	12 1/16	11¾	3¼	160
3 Flge.	105	24	16 1/16	17⅞	3⅞	300
4 Flge.	257	29¼	22 1/16	20⅝	4¾	500
6 Flge.	589	36⅜	29	25⅝	5⅞	1000

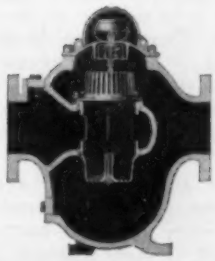
CREST METERS FOR BULK WATER DELIVERIES

For "bulk" water deliveries at periodic or continuous high rates of flow—i.e., where mains deliver water to adjacent townships; hydraulic elevators, cranes, pile-jetting apparatus, etc., the Crest Meter is recommended. Of the velocity type, a turbine is rotated by the water at a speed directly proportional to rate of flow. Among features is the hollow hard-rubber turbine revolving on agate bearing, resulting in minimum friction, maximum sensitivity, sustained accuracy. Standard Trident register and gear train features. All parts interchangeable.

Trident Crest Meters

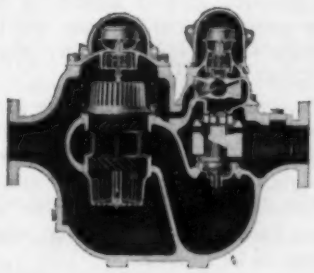
Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	65	12⅝	8½	16¼	6⅜	100
1½ Flge.	65	13	8½	16¼	6⅜	100
2 Scr.	83	15½	8⅞	16⅝	6⅞	160
2 Flge.	85	17	8⅞	16⅝	6⅞	160
3 Flge.	250	24	13⅝	27¼	13¼	350
4 Flge.	260	24	13⅝	27¼	13¼	600
6 Flge.	300	24	14⅝	28¾	14¾	1400
8 Flge.	500	26¾	17½	30¼	15⅝	2500
10 Flge.	800	30	26¾	29¼	13⅞	3800
12 Flge.	1200	36	30½	34⅞	16½	5800
16 Flge.	1950	42	36½	40⅞	19¾	11500

Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications



COMPOUND METERS FOR WIDE WORKING RANGES

Use this Compound Meter for services with a maximum demand beyond the range of equivalent disc meters—yet with the probability of occasional small rates of flow. Accurate over a wide working range. Measures high rates of flow through a Trident Crest Meter unit and small flows, which cannot be recorded accurately by the Crest, through a Trident Disc Meter unit. In addition to the standard Trident features of both these meters, a specially constructed valve automatically directs the water to the proper unit, depending on rate of flow. Single cast iron casing. All parts interchangeable.



Trident Compound Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	460	33	13⅝	27½	13¼	320
4	475	33	13⅝	27½	13¼	500
6	685	36½	14⅝	28⅝	14⅝	1000
8	970	42	17½	29⅞	15⅝	1600
10	1500	45 7/16	20⅝	29⅛	13⅞	2300

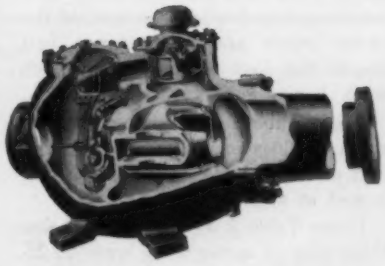
PROTECTUS METERS FOR FIRE SERVICE LINES

Designed for fire line use where both high and low flows occur, and loss of head is an important factor. Meets such requirements with (a) accuracy on all flows and (b) low loss of head plus reliability of operation, satisfying both Water Works officials and Underwriters. Measures low flows through a Trident Disc Meter unit. Large flows are measured proportionally by a Trident Crest unit. Water-way is clear, unobstructed. Both units have standard Trident features which insure accuracy, long life and low maintenance cost.

Trident Protectus Meters

Size In's	Wt. Lbs.	Lgth. In's Incl. Incr.	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	700	64⅝	22⅝	21½	8	400
4	900	67	24	24⅝	8	700
6	1600	83⅞	29	27½	10	1600
8	2250	89⅝	32⅝	30⅞	11¾	2800
10	3400	98½	38½	37⅝	14⅝	4400

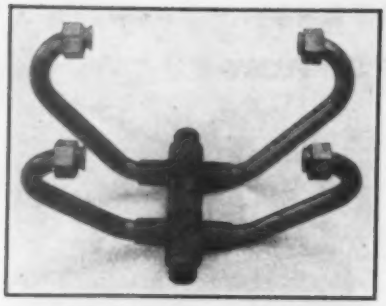
Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications



NEPTUNE METER COMPANY
New York 20, N. Y.

See Page R-186 for Branch Offices and Factories

For details circle 548 on inquiry card



TANDEM resetter for testing several meters in line

Note that the average accuracy of the service meters in the example is 92.0 percent. The average accuracy of service meters in another water works would be different from this value, and each plant must run its own tests and collect its own data in using this method.

In work of this kind, once averages are known it is simpler to consider the average. Therefore we divide the sum of Col. 7 by 10 to obtain the average registration of the service meters and do the same to Column 10 to obtain the average registration of the test meters.

Thus we find that our average service meter failed to register 430 gallons of water in the 30-day period of test, and is eight percent slow. In a year this would be 5,000 gallons. For this typical problem we shall assume that the rate was 40 cents per thousand gallons. Hence the one year gross loss in revenue for the average eight year old meter would be $2.00.

Next we shall calculate the gross loss during the eight years the meter was in service. We shall assume a straight line loss until a better system is known. Such a straight line loss chart for this average meter would appear as in Table 2.

Apply The Basic Rule

Now we can apply the basic rule: "In any period of time the highest net revenue of a metered water system is received when the cost of the meter repair and maintenance just equals the loss of revenue if such work is not done."

From Table 2 we see that in eight years the loss in revenue is $9.00. If cost of meter work is $8.50 the rule is met at about 7½ years.

From Table 2 we can see also that if the cost of meter work were $5.25, a six-year interval would be indicated.

Don't Forget the Variables

Again it must be emphasized that there are three variables in this calculation: a change in one will change the ultimate answer.

As an example, if the total of the meter water rate plus sewage surcharge averaged 80 cents per thousand gallons, the cumulative loss shown in the right hand column of Chart 2 would be twice that shown. If the other two variables, cost of meter repair and rate of slowdown were the same, a six year testing interval would be indicated.

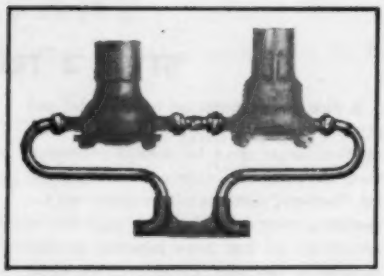
Rates are sometimes in steps, so that the calculations shown on Table 2 will have to be modified to show true registration loss. Also many rates include a "Minimum Charge" and the question must be answered as to what to do with meters on such accounts. A full discussion of this special case in metering is not possible here. Remember that on a minimum rate account, the customer is not being charged at a metered rate, but on a flat rate. Thus the meter becomes more of a watch dog than a register of water used.

A strict application of the basic rule would indicate that a meter which does not indicate a minimum bill should not be removed. In spite of that fact, we find that many good operators treat their minimum account meters in the regular category. Their reasoning is that special meter bookkeeping costs more than any saving in meter repair work.

If the series system appeals to you, periodic repetition of the test work should be done. Such work is not expensive.

For Larger Meter Sizes

This discussion so far has been based on revenue using a ⅝-inch meter. As meters increase in size, their potential revenue goes up as does the potential ability to lose revenues. You may wish to do series testing on ¾-inch and 1-inch meters. If not, we suggest as a rule of thumb that ¾ inch meters be classed with ⅝ inch meters; and 1 inch meters if they are properly sized as indicated by revenue received, they may be put on a system whereby they are repaired 40 percent oftener than the ⅝-inch size.



TANDEM resetter for testing two meters in line

In meters larger than one inch, the series system is difficult to use, but the basic rule of meter maintenance will apply.

Other Questions

Also, remember that whereas a disc meter will not speed up more than a possible two or three percent, a compound or velocity meter can become corroded, and cases are known of high over-registration. For such meters, testing in place with a disc meter in series should be done at much more frequent intervals than is indicated for the smaller size disc meters.

Another question, frequently asked is: "How sensitive should a repaired meter be when it leaves a meter repair shop." This is not an easy question to answer because of many variables, but the AWWA Committee 8610-O-Meters last year completed "Recommended Water Meter Test Specifications. The essence of the committee recommendations is shown in the accompany table illustration so labelled.

TABLE 2

Calculation of Gross Loss by Meter in 8 Years Service

Years in Service	Loss in Accuracy At End of Year	Gallons Under Registered	Loss For Year Per Account	Cumulative Loss in $
1	1%	625	0.25	0.25
2	2%	1250	0.50	0.75
3	3%	1875	0.75	1.50
4	4%	2500	1.00	2.50
5	5%	3125	1.25	3.75
6	6%	3750	1.50	5.25
7	7%	4375	1.75	7.00
8	8%	5000	2.00	9.00
9	9%	5625	2.25	11.25
10	10%	6250	2.50	13.75

Positive Displacement Meters

Size	Maximum Rate: Rate in G.P.M.	Maximum Rate: Test Quantity Gals.	Maximum Rate: Test Quantity Ft.	Maximum Rate: *Accuracy Limits in %	Intermediate Rate: Rate in G.P.M.	Intermediate Rate: Test Quantity Gals.	Intermediate Rate: Test Quantity Ft.	Intermediate Rate: *Accuracy Limits in %	Minimum Rate: Rate in G.P.M	Minimum Rate: Test Quantity Gals.	Minimum Rate: Test Quantity Ft.	Minimum Rate: *New Meters Accuracy Limits in %	Minimum Rate: **Repaired Meters Accuracy Limits in %
5/8"	15	100	10	98.5-101.5	2	10	1	98.5-101.5	1/4	10	1	95-101.5	90-101.5
3/4"	25	100	10	98.5-101.5	3	10	1	98.5-101.5	1/2	10	1	95-101.5	90-101.5
1"	40	100	10	98.5-101.5	4	10	1	98.5-101.5	3/4	10	1	95-101.5	90-101.5
1-1/2"	80	1,000	100	98.5-101.5	8	100	10	98.5-101.5	1-1/2	100	10	95-101.5	90-101.5
2"	120	1,000	100	98.5-101.5	15	100	10	98.5-101.5	2	100	10	95-101.5	90-101.5
3"	250	1,000	100	98.5-101.5	20	100	10	98.5-101.5	4	100	10	95-101.5	90-101.5
4"	350	1,000	100	98.5-101.5	40	100	10	98.5-101.5	7	100	10	95-101.5	90-101.5
6"	700	1,000	100	98.5-101.5	60	100	10	98.5-101.5	12	100	10	95-101.5	90-101.5

Current Meters

1-1/2"	80	1,000	100	97-103	15	100	10	97-103	7	100	10	95-103	90-103
2"	120	1,000	100	97-103	20	100	10	97-103	10	100	10	95-103	90-103
3"	250	1,000	100	97-103	30	100	10	97-103	15	100	10	95-103	90-103
4"	400	10,000	1,000	97-103	50	1,000	100	97-103	20	1,000	100	95-103	90-103
6"	1,000	10,000	1,000	97-103	100	1,000	100	97-103	30	1,000	100	95-103	90-103
8"	1,600	10,000	1,000	97-103	200	10,000	1,000	97-103	50	1,000	100	95-103	90-103
10"	2,500	10,000	1,000	97-103	300	10,000	1,000	97-103	75	1,000	100	95-103	90-103
12"	4,000	10,000	1,000	97-103	400	10,000	1,000	97-103	100	1,000	100	95-103	90-103
16"	7,000	10,000	1,000	97-103	600	10,000	1,000	97-103	150	1,000	100	95-103	90-103

Current meters larger than 2" should preferably be tested in field by comparison with test meter.

Compound Meters***

Size	Maximum Rate: Rate in G.P.M.	Maximum Rate: Test Quantity Gals.	Maximum Rate: Test Quantity Ft.	Maximum Rate: *Accuracy Limits in %	Intermediate Rate: Rate in G.P.M.	Intermediate Rate: Test Quantity Gals.	Intermediate Rate: Test Quantity Ft.	Intermediate Rate: *Accuracy Limits in %	Minimum Rate: Rate in G.P.M.	Minimum Rate: Test Quantity Gals.	Minimum Rate: Test Quantity Ft.	Minimum Rate: *New Meters Accuracy Limits in %	Minimum Rate: **Repaired Meters Accuracy Limits in %
1-1/2"	80	1,000	100	97-103	15	100	10	97-103	1/4	10	1	95-103	90-103
2"	120	1,000	100	97-103	20	100	10	97-103	1/4	10	1	95-103	90-103
3"	250	1,000	100	97-103	30	100	10	97-103	1/2	10	1	95-103	90-103
4"	350	10,000	1,000	97-103	50	1,000	100	97-103	3/4	10	1	95-103	90-103
6"	700	10,000	1,000	97-103	100	1,000	100	97-103	1-1/2	100	10	95-103	90-103
8"	1,200	10,000	1,000	97-103	200	10,000	1,000	97-103	2	100	10	95-103	90-103
10"	1,600	10,000	1,000	97-103	300	10,000	1,000	97-103	4	100	10	95-103	90-103
12"	2,400	10,000	1,000	97-103	400	10,000	1,000	97-103	7	100	10	95-103	90-103

Compound meters larger than 2" should preferably be tested in field by comparison with test meter.

*Accuracy Limits recommended also for repaired meters.

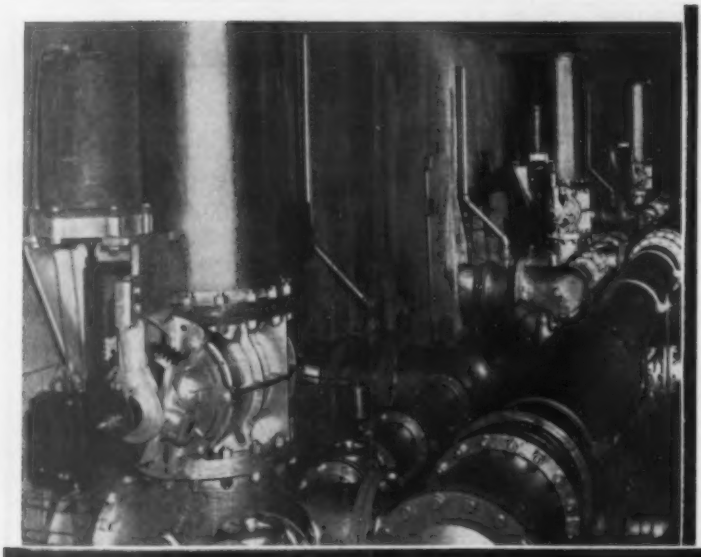
**Tabulated minimum rate accuracy limits for repaired meters considered as those which can be achieved with most meters and good meter repair procedures.

**Any meter, regardless of age, which cannot be repaired to test 80% or better, on the minimum flow test should not be placed in service.

***Compound meters should also be tested at a rate within the "change-over" range of flows. As this range is variable depending on make of meter and sizes of bypass (or small) meter unit, no one set of definitive rates can be established. Minimum required accuracy at any rate within such "change-over" range of flows is 85%. The bypass (or small) meter unit of compound meters should also be tested at a rate as near as possible to the maximum test rate listed for disc meters of same size (without causing compounding valve to open). Accuracy limits on this test 98.5-101.5%. Specific rates cannot be readily tabulated for this test due to various makes of compound meters having different sizes of small meter units, and being designed for different rates of flow opening the compounding valve.

Recommended test specifications for water meters

[For meters covered by AWWA Std. Spec: C700-46, positive displacement meters; C701-47, current meters; C702-47 compound meters]



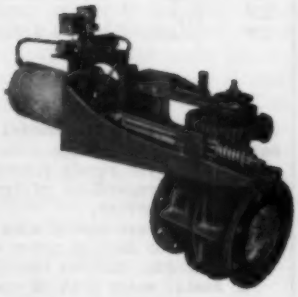
DeZurik Valves

The growing number of DeZurik Valve installations is the surest indication of their acceptance in the water and sewage fields. Consulting engineers, superintendents and plant personnel agree that DeZurik Valves have definite advantages which put them far above all others in dependability, long life and economy.

DeZurik Valves' *exclusive* Eccentric Action guarantees dead-tight shut-off. The plug is pivoted eccentrically in the valve, matching the eccentrically-raised seat. There's no friction, no binding, no scraping—because the plug touches the valve body ONLY when the valve is closed! You get *easy* operation—every time—without lubrication!

DeZurik's segmental plug has a single seating surface; it will not trap liquids where they can digest or freeze, necessitating expensive repairs and drain plugs. The plug turns easily because there's no friction. It seals dead shut on any flow because of its resilient facing which seals *around* solids lodged on the seat. The resiliency of the plug facing also resists abrasion from solids in the flow. And it is self-compensating for wear.

DeZurik Control Valves provides the modern plant with positive control on any line. Where throttling is required, DeZurik Valves furnish precisely controlled remote operation, frequently at a lower cost than an ordinary valve without a positioner! Operators on DeZurik Valves are mounted parallel to the pipe line, offering a more compact installation which can be placed in any location where there is little more than room for the pipe itself.



DeZurik Valves have many other advantages! Their nickel seats last longer; they are available in a complete range of body materials, with a full complement of remote operators, and in sizes from ½" thru 20". For more details on DeZurik Valves, see the representative in your area, or write to

DeZURIK CORPORATION
SARTELL, MINNESOTA

For details circle 549 on inquiry card

Porous Plate Filter Bottoms

by FRANK C. ROE

Senior Engineer, Technical Service Refractories Div., The Carborundum Co.

Perth Amboy, N. J.

■ THE FIRST NORMAL sized porous plate installations in municipal filter plants were made in 1936 at Denver, Colo. and Grand Rapids, Mich. In the twenty-one years that have elapsed, more than 400 installations of Carborundum's "Aloxite" plates have been made all over the world under widely variable conditions.* (See Fig. 1)

Unquestionably, the need for water treatment, including filtration, persists as one of man's expanding problems. It is just as certain that new methods of filtration will continue to develop and that as long as the rapid type back washed units are used, the perfect filter bottom will be like Utopia—never quite attainable.

By eliminating the graded gravel support for filter media, as typically illustrated in Fig. 2, the porous plate bottom comes close to an ideal structure, even though there are limitations in certain areas of use, as will be related later. Operation problems growing out of "air binding," non-uniform backwash, etc., that are inherent with any underdrain system that uses graded gravel, are eliminated by the use of porous plates and cost of filter maintenance is thereby reduced.

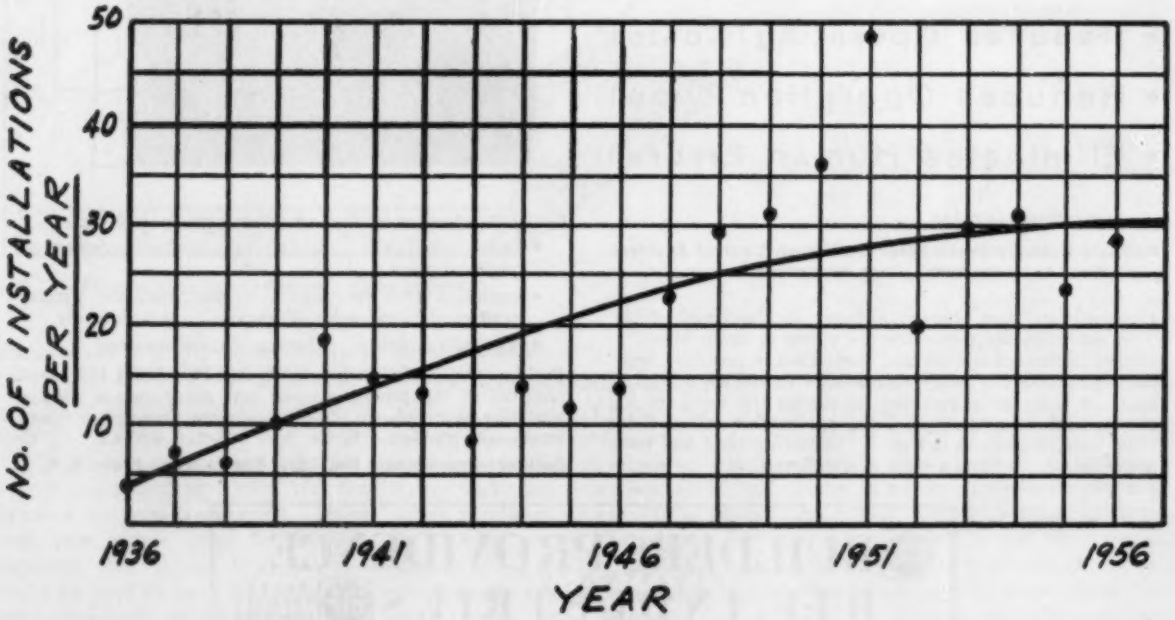
One example of maintenance cost that is of major consequence during the present period of ever increasing labor cost is the expense of removing, regrading and replacing an upset filter. Simultaneously, the value of the time that a filter is out of service for rebuilding, frequently can be a critical factor. Porous plates can eliminate these costs.

It was the potential benefit of elminating graded gravel filter media support as provided by porous plate filter bottoms, that originally appealed to engineers and continues to be the principal point of advantage. It was, in fact, the reason for the original developments more than a quarter century ago at Sacramento by Harry M. Jenks,[1] at Windsor, Ontario by Messrs. Gore, Nasmith and Storrie, at the University of Texas by Messrs. Jessen and Hinyard[2] and at Providence by Professor T. R. Camp,[3] all of which have been reported more or less completely. It is significant that subsequent reports in the literature,[4-10] which are all based on the currently used large pore ceramically bonded aluminum oxide porous plates, invariably stress the money saving benefits of completely eliminating graded gravel.

Initial Response

Because water supply engineering by its very nature must be sound and conservative, many designing engineers were hesitant to suggest the use of porous plate underdrains until "satisfactory performance is proved elsewhere" or until "all the bugs are worked out." There is nothing extraordinary about such a reactionary attitude. It is fortunate, however, in the interest of technical progress that there were a number of pioneers with

* Installations of Carborundum "Aloxite" plates only; no record of competitive installations.



THE GROWTH of porous plate filter bottom installations since 1936 (Fig. 1)*

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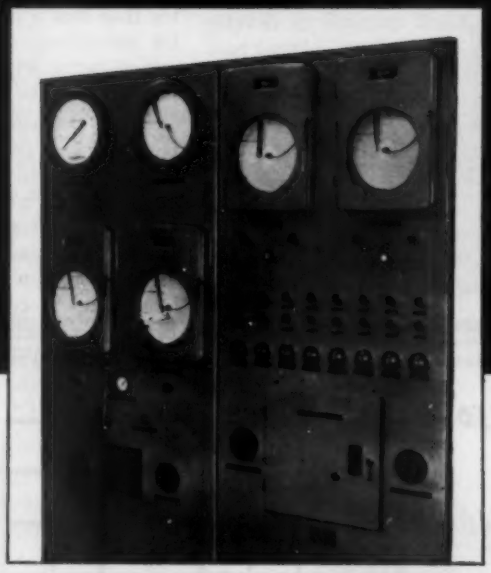

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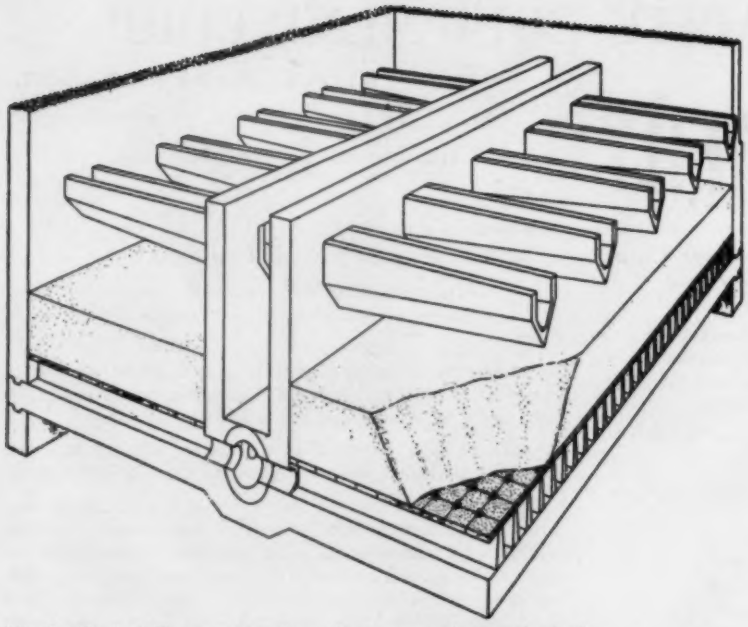

FIG. 2—Typical filter construction using porous plate underdrains.

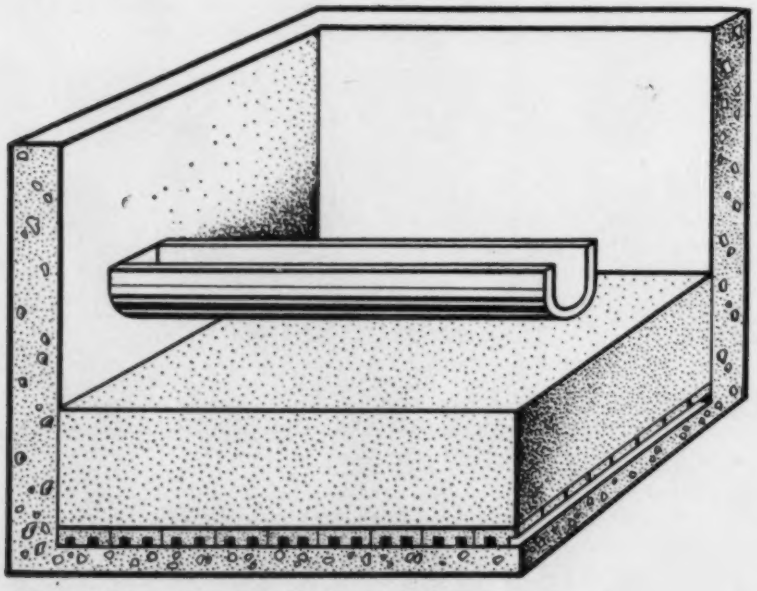

FIG. 3—Filter with channeled porous plate bottoms.

the courage to put the new idea into use when probable advantage appeared to overshadow possible difficulties.

The pioneering paid off. As previously suggested, perfection was not attained nor was it expected. There was soon ample proof to skeptics, however, that porous filter bottoms could be used in most instances in a normal manner, permitting owners to reap the ultimate benefit of the idea.

Present Status

The extensive background of experience derived during the past twenty-one years could not be assembled in a precise or tabulated report form with data covering each and every condition of use. It is likely, as a matter of fact, that no two conditions of use out of the several hundred installations, are completely identical. At the same time, this report provides some interesting factual information concerning the basic experiences.

Within the past few months an independent survey organization submitted a questionnaire to all engineers in the United States who engage in water supply work. The reasonably good response (26 per cent) that was received, provides a consensus that is significant. These results from the survey are particularly cogent:

1. With a single exception, all consulting and designing engineers who have specified base or alternate use of porous plate underdrains, stated that they would continue to do so.
2. An overwhelming majority of engineers who responded stated that they now believed porous plate underdrains were acceptable with certain limitations, e.g., use in lime softening plants.
3. A considerable number of engineers replying to the questionnaire stated that more information on the porous underdrain and its performance, was desirable.
4. An extremely small number, all of whom had had *no experience* with porous plate underdrains, were negative or otherwise indicated that they would not consider such construction.

The recent survey strongly supports observations which the author has been able to make during the past twenty-one years of close association with the development and use of porous plate filter bottoms. These very candid observations are more specifically cataloged and enumerated as follows:

Application

1. Where the function of filtration is removal of flocculent solids from water that is pretreated and settled in a normal manner and is otherwise stable as to pH, satisfactory performance of porous plate underdrains will be experienced indefinitely and the full benefits derived from elimination of graded gravel filter media support.

The only other qualification is that filtered water must be used for backwashing which, of course, is normal practice. The average diameter of pores in porous underdrain plates is more than twice the average diameter of interstice in 0.5 mm filter media, a fact that some engineers do not realize. Consequently, trace solids that penetrate filter media will invariably pass through underdrain plates.

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Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthrafilt and sand and saves on freight and handling charges.

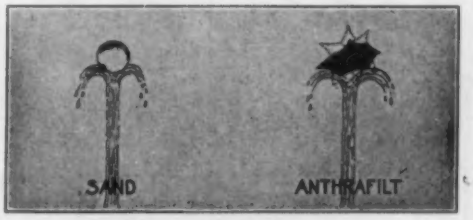
Filtration Characteristics

Anthrafilt granules are irregular shaped and of varying densities. **Weights run about 53 pounds per cubic foot as** against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. The uniformity coefficient is less than 1.75 in all sizes. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in Existing Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

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2. Where the function of filtration is to remove precipitated calcium carbonate from lime softened water and the reaction has not been stabilized by recarbonation or other means prior to actual filtration, it may be unwise and/or uneconomical to use porous plate bottoms. Continued reaction through the filter units would most certainly result in incrustation of filter underdrains to a serious degree. Removal of such incrustation by acid treatment can be accomplished but if too frequent, it can be economically prohibitive.

3. Where the function of filtration is to remove precipitated iron or manganese hydroxide, it is equally impotrant to the success of porous plate underdrains to insure adequate pretreatment. Without thorough aeration followed by ample periods for coagulation and settling, precipitation of hydroxides will occur throughout the filter so that coating and ultimate clogging of pores in the underdrain system will develop.

As in the case of carbonate incrustation, iron and manganese hydroxide solids can be removed from porous plate underdrains by acid treatment. The practicability of such treatment has not been proved, however.

4. Where untreated waters are filtered, as in the case of recirculating swimming pool water, low turbidity surface supplies and the like, porous plates can be used with complete success. It is important, however, to select filter media of a size that will provide the desired water quality.

In installations of this character, it is normally desirable to use filtered water for back washing. Many such installations have given long and satisfactory service without filtered water backwash, but the practice is not recommended and probably is prohibited by many State Health Department operating codes.

5. Where porous underdrains are used to support Zeolite in softeners of either gravity or downward flow pressure types, complete satisfaction is experienced. This extremely valuable benefit of positive protection against loss of expensive ion exchange media is obvious. Porous plates are unaffected by brine (or acid) used for regeneration. They should not be used however where strong caustic is used for cation regeneration, since caustic will attack the ceramic bond and cause ultimate structural failure.

FIG. 4—Concrete pier support for plain plates.

Design

During these 21 years of experience, some interesting and important design and installation ideas have developed; some have proved sound, others have been discarded.

A. *Channeled Plates.* The original ceramic bonded porous underdrain plates with channels formed therein assembled (as shown in Fig. 3) to correspond to a system of laterals on the filter floor, was simply too costly. Also, filter size is limited by hydraulic considerations related to the area of the channels. Use of this idea is now confined to small units where there is an extremely limited operating head available.

Incidentally, it is essential to anchor such plates to the filter floor with bolts to insure stability. A permanent adhesive to bond plates to the floor is conceivable but none has been discovered.

B. *Pier Support—Plain Plates.* During the period of successful development reported herein, more installations have been made with plates bolted to concrete piers than any other single design. Fig. 4 illustrates the usual construction, although many variations exist due to different methods of introducing wash water.

C. *Long Bolt Support—Plain Plates.* Fig. 5 illustrates the initial 3-point long bolt support construction conceived by T. R. Camp, providing unobstructed space below plates for uniform wash water distribution. There are now a considerable number of plants in which this design has been utilized satisfactorily.

In recent years a predominant number of plants have been built with this simple long bolt support construction because it is lower in cost than any other design offered to date. Most of the designs have been based on bolts at corners only, rather than the 3-point principle which was found unnecessary in the interest of uniform support and

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Over 60 years devoted exclusively to the manufacture and installation of water rectification equipment. Roberts Filters are now clarifying more than five billion gallons of water daily. Our installations are serving hundreds of municipalities and institutions with drinking water and many industrial establishments are dependent on Roberts Filters for process water.

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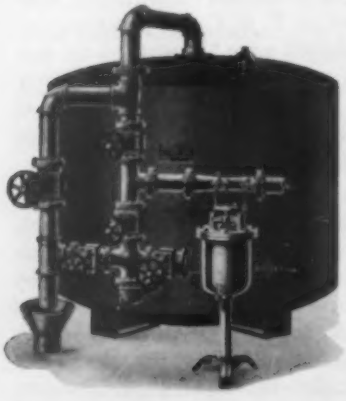
For services where the needs are not sufficiently exacting to justify Gravity Filters, we can furnish closed Pressure Filters of the most modern design.



Style "L" Vertical Pressure Filter

Vertical Filters are available in standard sizes from 12 to 96 in. diameter.

Where large capacity is involved we recommend Horizontal Filters. These are all 8 ft. diameter and in varying lengths from 10 to 25 ft.

Pressure Filters are ideal for Swimming Pool Recirculation and, to accompany them, we can supply all items of equipment forming the recirculating plant.

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We suggest our Wheeler False Filter Bottom for the elimination of metal in the Filter Underdrainage System and for a perfect distribution of wash water at minimum loss of head.

The Wheeler False Filter Bottom is cast in place in one pouring, eliminating shifting of sections; each pyramidal depression is so constructed that there is no lateral shifting within its area.

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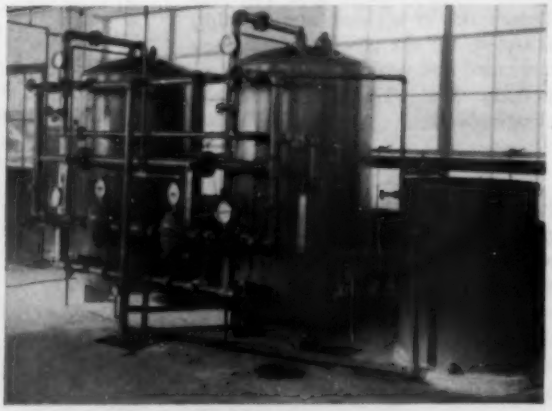
Roberts Zeolite Water Softeners are of improved design and rugged construction. The installation illustrated below serves one of the country's leading Textile Finishing Establishments.

In considering Water Softening the Boiler Water Supply should not be overlooked as most Boiler troubles—including pitting, scale, incrustration and caustic embrittlement—can be traced to improperly treated water. We will be glad to make recommendations in connection with any Water Softening Problem.

All quotations are accompanied by guarantees that the equipment will fulfill any and all of the requirements for which we recommend it.



Installation of Zeolite Water Softeners

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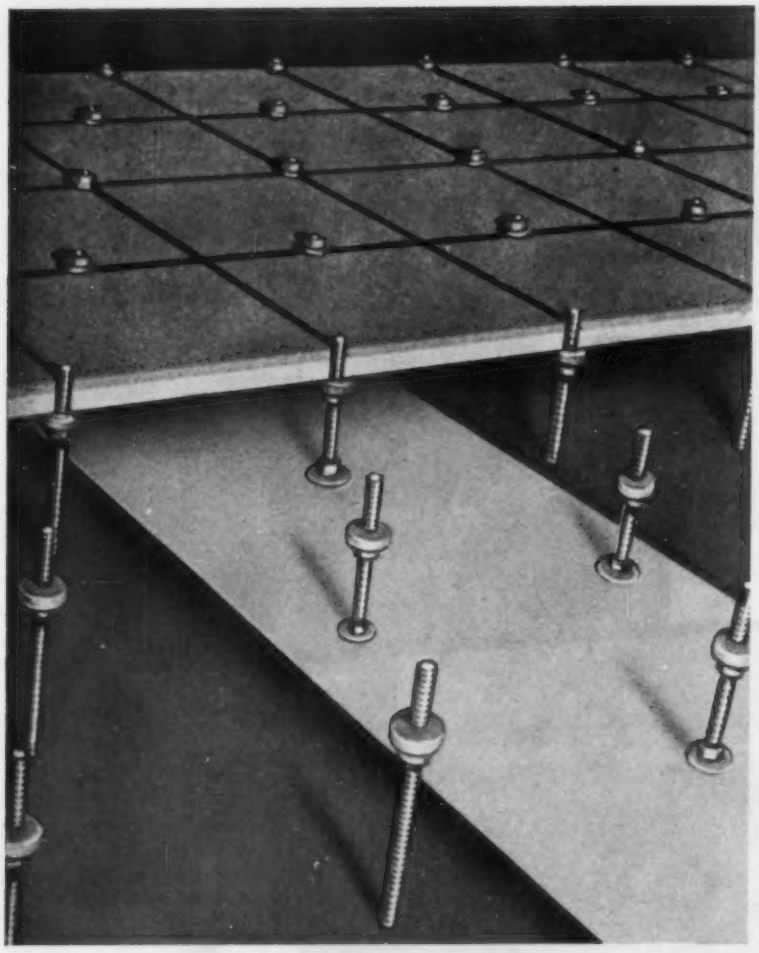

FIG. 5—Long bolt support for plain plates.

anchorage. Support and anchorage at the 4-corners of plates is completely satisfactory because the joint sealing compound, also used between plates and bearing washers, prevents plate stress. The 4-point design is simpler in layout and construction. Furthermore, serious cantiliver stress of plate corners is avoided during construction due to the weight of workman standing on an unsupported corner.

A complete long bolt design filter bottom "package" is offered by Christy Firebrick Co., St. Louis, Mo. It comprises plates, stainless steel bolts, square washers and nuts and joint sealing compound along with adequate instructions for installation in several ways adapted to existing or new structures.

D. *Hardinge Co.—Automatic Back Wash.* This is a complete filter plant "package" that is both unique and outstanding in economic possibilities for many situations. A single filter unit actually is a complete self contained plant that will deliver a uniform supply of filtered water continuously.

This condition is achieved, as may be evident in Fig. 6, by a traveling wash compartment that segregates one small portion of the filter at a time for washing by a self contained pump while the balance of the unit continues to operate on the filter cycle in a normal manner. Porous plates, supported by a structural steel framework and with shallow steel compartments across the filter above, comprise the only practical type of underdrain system that can be used with such a design.

E. *Beam Support.* Structural steel beams (channels) set in one direction, with plates bolted thereto as illustrated by Fig. 7, is a construction frequently used for pressure filters. A majority of the pressure filter installations of porous underdrains incorporate this design principle.

Complete pressure filter units utilizing porous plate filter bottoms of this general design, are now available from Black, Sivalls and Bryson of Oklahoma City, Okla.

F. *Barstow Tile Support.* In 1950, E. D. Barstow of Akron, Ohio, conceived the use of a vitrified clay tile block design for porous plate underdrains and applied it to two or three plants in Ohio. Fig. 8 is a cross section of this tile block design with the porous plate underdrain installed therein.

This idea has merit because of low cost and the elimination of hold down bolts. It is not as flexible in adaptation to filter construction as some other designs since a central raised wash water box manifold is required, with wash gullet above.

Installation

The old adage about a "chain being no stronger than its weakest link" certainly applies to filter construction and designs based on the use of porous plates are no exception. Experience has shown the need to follow these steps carefully:

1. Check each plate for soundness when it is laid (they can be cracked in shipping and handling).
2. Make certain that every bolt is thoroughly anchored.
3. Thoroughly clean and wash floor and area below plate elevation.
4. Be sure that all joints between plates are sealed.
5. Protect plates with covering during joint sealing, except for joint areas, against excess cement and foreign matter.
6. Tighten nuts over washers hand tight only, or to 5 lb with torque wrench, to avoid plate corner cracking.

It is apparent that none of these requisites is difficult or complicated to follow. In simple terms, installation technique can be summarized as "common sense" and "good workmanship." The reader may add an aside here that "such human attributes may not be easy to find in the modern labor market." The only answer to that is good supervision of installation.

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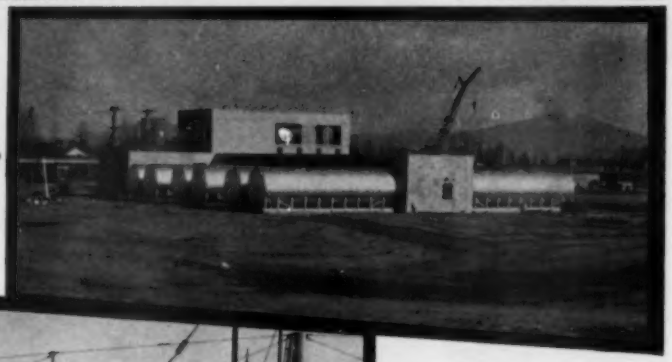

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CONTRAFLO type "CW" thickeners and clarifiers for neutralizing of plating wastes.

Master control table for 3 gravity filters. Stainless steel table top with pneumatic pilot valve operators.

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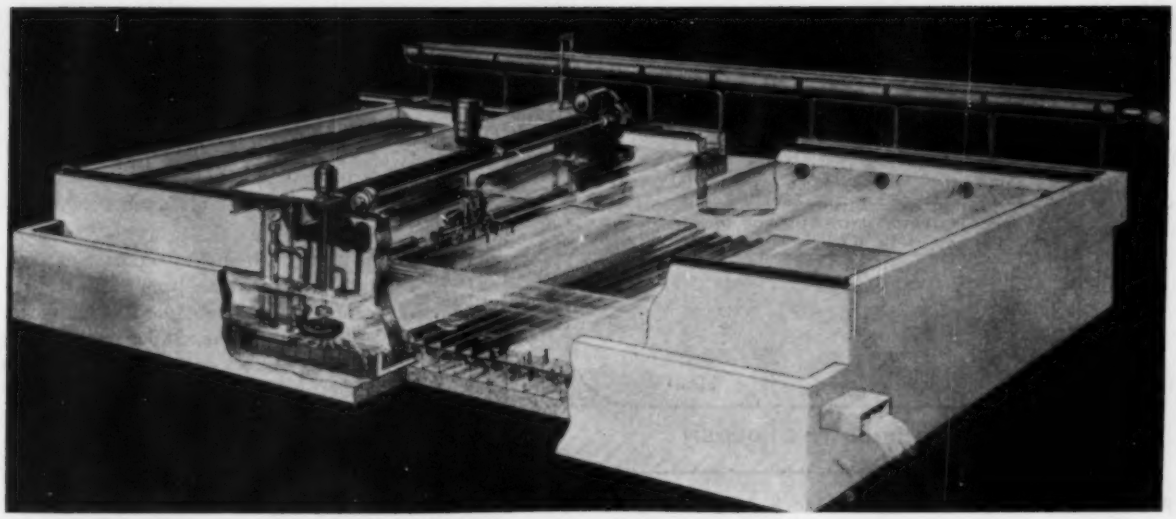

FIG. 6—Hardinge automatic back wash filter.

Materials

1. *Plates.* Porous underdrain plates proper are composed of fused aluminum oxide granules and a ceramic bond. After plates are formed, they are kiln fired at approximately 2435°F. Such a material is, of course, permanently unaffected by water or any condition of oxidation. It is likewise resistant to commercial acids as may be used for cleaning filters. Porous plates are attacked by strong caustic but are not affected by a mild 5 per cent solution of sodium hydroxide as may also be used infrequently for cleaning of filters.
2. *Bolts.* With the thought of almost permanent balanced construction in mind, it usually is desirable to use stainless steel for hold down bolts. On the other hand, if the water is not aggressive, ordinary low cost galvanized bolts are quite satisfactory as is evidenced by extensive use of same during the past 21 years.
3. *Joints.* A wide variety of materials has been used for joint sealing between plates and as a means of providing uniform bearing on piers, etc. The two most extensively used materials are phenol free petroleum asphalt and Lumnite cement, mixed with fine sand. The coarse texture of plates insures a good bond with almost any cement that is thoroughly applied.

Quite recently some installations have been made with rubber gaskets. Cross sections of such gaskets for use between plates and between plates and filter wall, are illustrated by Fig. 9. They are obtainable from Oliver Tire and Rubber Co. of Oakland, Calif.

Co··

No report on an equipment or structural development is complete without some answer to the question, "how much?" Obviously, the unit cost factor for porous plate filter bottoms

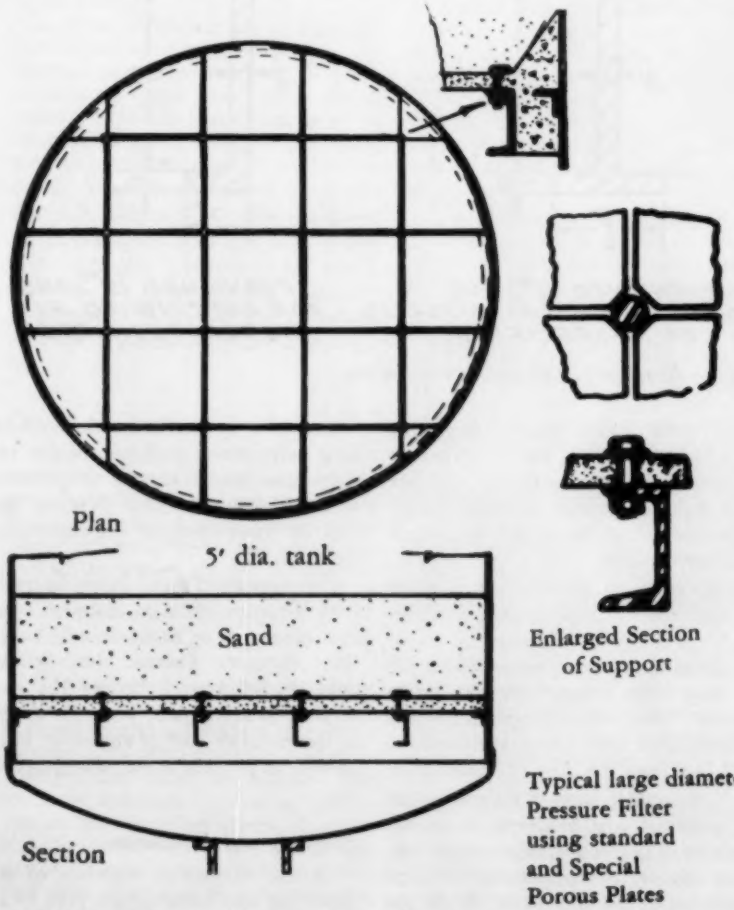

FIG. 7—Structural steel beams (channels) set in one direction with plates bolted thereto.

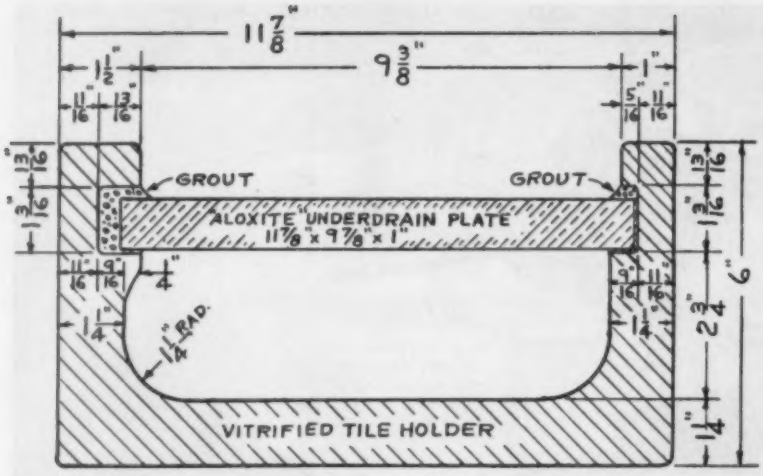

FIG. 8—Barstow vitrified clay tile block design for porous plate underdrain support.

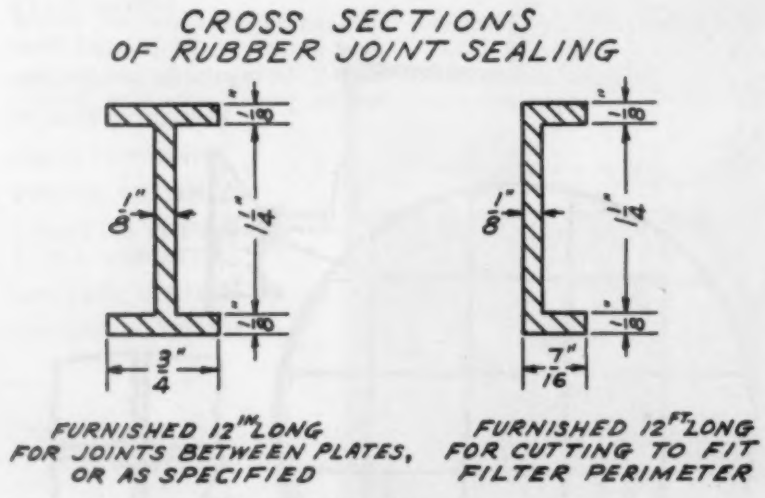

FIG. 9—Cross-section of rubber joint sealing.

varies with design, location and filter area. Other factors, such as, whether a job is new or reconstructed, whether it is done by owners, workmen or by contractor, can have an important bearing on cost.

The price of porous plates alone at the end of 1957 averaged about $4.50 per sq ft delivered, as compared with a price of about $1.80 per sq ft in 1936, when they were introduced. Thus, cost of plates alone has inflated less than other commodities and less than the cost of installation.

A reasonable basis of estimating total installed cost has been to double the cost of plates and then add or subtract slightly to compensate for local conditions. On this basis, $9.00 per sq ft can be used as the starting point.

Incidentally, this cost estimate assumes false bottom construction with long bolts per Fig. 5 which was reported as lowest in cost at present. Inflated labor rates have increased the cost of other designs disproportionately.

One important point should be made here if comparisons on installed filter cost alone are to be made with other filter designs. Porous plates eliminate graded gravel, hence; the cost of that item in place must be added to the installed cost of any other filter bottom to provide a realistic comparison.

Summary and Conclusion

In the interest of economy of engineering and construction plus localized responsibility, the modern trend to "package" designs for any unit of equipment seems logical. The lack of a complete unit, however, has handicapped progress in the use of porous plate filter bottoms during most of the 21 year period since these plates were introduced. Engineers have had to piece together plates and accessories with their own ideas of design and construction.

It is gratifying to report that definite progress has been made in recent years to overcome this handicap. At least three companies are offering complete filters equipped with porous plate filter bottoms and one company offers a unit adapted to any filter design.

This report on experiences has included some detail on design, installation and materials in order to simplify the task of engineers in adapting porous plate filter bottoms to plant designs and specifications. The same information should help additional filter equipment manufacturers and/or contractors to establish and offer so-called "package" filter bottom units.

It is entirely reasonable to conclude on the basis of the points of achievement discussed herein, developed over 21 years of robust growth, that porous plate filter bottoms are now established as functionally sound where properly applied, and economically beneficial.

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Taste and Odor Control

With Activated Carbon

by E. A. SIGWORTH

Water Purification Division of Industrial Chemical Sales Division of the West Virginia Pulp and Paper Co.

WATER WORKS operators today are called upon to furnish an abundant supply of water, and to make it readily available to meet the many and varied uses of our modern civilization. Present water purification practice has developed to the point that the great majority of plants are delivering clear, safe water at all times, but this excellent record is often marred when plants deliver an unpalatable water.

The water works operator fully realizes that presence of tastes or odors in the water supply is not necessarily an indication that the water is unsafe to drink. The average consumer, however, feels that odor in water is an indication of pollution, and he may travel great distances for a more palatable but perhaps less safe supply. Such experiences have frequently resulted in water-borne epidemics in communities, in spite of the fact that the municipal supply has been thoroughly protected by application of chlorine for disinfection purposes. From the viewpoint of the health of the community as well as good public relations, it is, therefore, almost as essential to furnish a palatable water as it is to furnish one which is clear, sparkling and free of any harmful impurities. If bottled water is widely used in a community, it is time to take a critical look at the water purification processes.

With existing methods for taste and odor control, there is no longer any excuse for delivering water containing any odors, whether they be chlorinous, earthy, fishy, moldy, musty, or any of the legion of odors possible in present-day water supplies.

A great number of plants throughout the country are consistently delivering palatable water at all times even though their raw water may at times contain high concentrations of odor. This trend towards delivering a quality product naturally costs money. If, however, the water plant official will calculate the cost on a per capita basis, he will find that it will amount to only a few cents per capita per year. Certainly no consumer could object to paying such a minor cost for a consistently palatable water.

Causes of Odors

Algae growths are the most frequent offenders where taste and odor are concerned. Although there are many varieties of algae, those most likely to cause taste and odor are limited to about 25 to 30 species. During their life cycle, these algae give off odorous compounds to the water, and each algae type will give off its own characteristic odor.

A more recent theory on algal type odors has been proposed. This theory is based on the association of actinomycetes with algal growths, and it is reported that odors are actually due to these associated growths rather than to the algae themselves. Regardless of whether odors are due to algae or actinomycetes, the fact remains that such odors still do constitute the most frequent cause of odor in water supplies. The second most frequent cause of odors is decaying vegetation resulting from decomposition of vegetable matter such as grass, under-water weeds, leaves, etc. Odors caused by industrial wastes are becoming much more frequent with the great industrial expansion throughout the country. Although industrial waste odors are less frequent offenders, the concentration of odors can frequently be very extreme. Under such conditions, the water plant official must often use every available method to reduce these odors to a palatable level.

The statement "an ounce of prevention is worth a pound of cure" is very appropo where odors are a serious problem. Therefore, preventive measures should be adopted, such as copper sulfate treatment for algae control, dredging or damming off shallow areas, and cooperation with industrial plants on the watershed area in order to attempt to reduce trade waste pollution.

Evaluation of Odors

The development of the "Threshold Odor Test" has provided the water works industry with a satisfactory means for odor evaluation. This test involves diluting a sample of water with varying amounts of odor-free water until the point is reached where odors are just detectable, and further dilutions show no detectable odor. By this method, odor concentrations can be assigned definite numbers directly proportional to the odor concentration. For example, an odor number of 20 would be 10 times stronger than an odor number of 2. Thus, this test provides the water works operator with a means of determining when it is necessary to institute corrective methods for odor control.

• Ed Note: Although tastes and odors are generally considered to be a summer problem, we are apt to forget that this problem exists in the warmer states from early spring to late autumn and the year around where industrial wastes are involved.

With this test, it is possible to measure the relative efficiency of various treatment methods and chemicals, to determine when the water is palatable, and to determine the best point of application for corrective treatment. It has been estimated that a threshold odor value of 5 will normally constitute a palatable level for the average consumer. This value assumes an observer with average sensitivity and is based on odor evaluations being conducted on heated samples (60°C), which gives higher odor values than those determined on cold samples. If the operator is super-sensitive to odors, the level of palatability might have to be increased and vice versa.

Activated Carbon

Activated carbon, as most frequently used in water treatment, is a very fine black powder. It acts by the phenomenon termed adsorption, which should not be confused with absorption. The concentration of certain specific substances at exposed surfaces is known as adsorption. On the other hand, the picking up of water by a sponge is known as absorption. If a container is filled with a dye solution and sponge inserted in the solution, absorption takes place. The sponge takes up both water and dye without any change in concentration. Removing the sponge and squeezing it would be the same as pouring some of the dye solution out of the container.

On the other hand, if a piece of clean cloth is dipped into the dye solution, there will be a greater proportion of the dye taken up on the cloth. If successive pieces of cloth are dipped into the dye solution, it will be possible to note a distinct lightening of the color of the dye solution. This phenomenon of chemical substances adhering to solid surfaces is known as adsorption.

BAG LOADING dust free dry feeder mounted on scales

ROTODIP chemical feeders for activated carbon slurry

If activated carbon is added to a dye solution, it is frequently possible to obtain complete removal of the dye by adsorption. This phenomenon is explained by exposure of clean surfaces, where impurities can concentrate and thus be removed from solution. This is one of the reasons that the carbon used in water purification is such a fine powder. Extremely small particles result in a greater degree of surface exposure, and the porous structure of activated carbon adds to this great amount of surface. Extremely clean surfaces may be considered as the really active patches on which maximum adsorption takes place. So great is the surface exposure obtainable with activated carbon that it has been calculated that one solid cubic inch of activated carbon can account for internal and external surface of approximately 10,000 square yards. It has also been estimated that one gram of activated carbon (about one normal heaping teaspoonful) will contain approximately 120 billion particles.

The fineness of the carbon particles, coupled with their porous character, gives another advantage in water treatment by permitting the carbon particles to disperse widely throughout the water and remain suspended for long periods of time. This dispersion and suspendability permits greater opportunity for odorous substances to come in contact with the active surfaces, which then attract and hold the impurities on the carbon surface. As the carbon particles settle out or are removed by filtration, the odorous compounds are also removed. Thus adsorption of taste and odor with activated carbon actually removes the offender from the water. Activated carbon does not change the odor to some less offending compound nor does it mask objectionable odors.

Dry Feeding Activated Carbon

Activated carbon is insoluble in water and since it is rather difficult to wet, must be applied as a slurry. It can be fed by dry-feed machines which proportion the dry carbon, after which it is wet in a solution box and subsequently applied as a carbon slurry. The predominant method of applying carbon is through dry-feed machines, many of which are available on the market today.

Occasionally some difficulties are encountered with dry-feed machines, so that the following suggestions are

worthy of consideration. The feeding hopper should be so designed that powdered carbon will not bridge in the hopper, thus preventing carbon from reaching the feeding mechanism. The capacity of the dry-feed machine should be more than ample to take care of the most severe odor condition likely to develop within the water treatment plant. The solution box should be designed so as to wet the carbon completely, and the water ejector should be of ample size and capacity to carry the carbon slurry away, even when the machine is operating at maximum capacity. All feed machines handling carbon should be equipped with dust collecting systems to eliminate escape of some of the fine particles as dust.

Slurry Feeding

In the early development of activated carbon in the water field, many plants used slurry methods of feeding. As activated carbon assumed a permanent place in water purification practice, dry feeding equipment was adapted and later specifically designed for handling carbon. Many of the large users are returning to slurry feeding methods, now that carbon can be delivered in bulk hopper cars.

When the shipment arrives at the plant, the carbon is discharged through the hopper bottoms into underground tanks. Here the carbon is slurried with water and stored until it is needed. When it is to be used, the carbon slurry is pumped to proportioning devices such as Rotodip feeders, displacement pumps, etc. and thence to the point of application. Actual development of this apparently simple procedure was fraught with many difficulties, such as wetting the carbon, design of equipment, etc. Credit for developing this method of feeding into a practical and efficient procedure should go to water treatment personnel of the City of Chicago. Since the first installation at their South District Plant in 1949, perseverance in improvements has finally resulted in solving the many problems encountered. For information on the subject their reports should be consulted.

Points of Application

In a water treatment plant, carbon should be applied at a point prior to filtration or, if no filters are available, prior to coagulation and settling. Thus in the normal water treatment plant, carbon can be applied to the raw water, mixing basin, settling basin or directly to the filters.

Where odors develop suddenly they may get through the plant before being detected; when this happens the carbon should be applied either on top of the filter or to the filter influent. In this manner, carbon is applied to that water which will first reach the consumer. This point of application is most frequently reported to give the greatest efficiency from the carbon for removal of tastes and odors. In many cases, surprisingly low carbon dosages are reported to give exceptionally good results in removing tastes and odors from water supplies by application to filters. Where odors are usually at low concentration or appear at infrequent intervals, this point of application is usually recommended.

If high dosages of carbon are necessary to correct an odor condition, application of carbon to the filters may result in high loss of head and possibly in the passage of carbon through the filter beds. Therefore, where carbon is used continuously, it is recommended that the point of application be moved so that it is applied at a point appreciably ahead of filtration. Also, where dosages in excess of 50 lb per mil gal (6 ppm) are necessary, carbon should not be applied to the filters for any prolonged period of time. Under such circumstances, application to the mixing basin or to the raw water is recommended. In some cases, carbon has been applied part way through the settling basin, but caution should be taken to insure that the carbon will have an opportunity to disperse rather uniformly throughout the entire body of water to be treated.

Effect of Other Chemicals

Most efficient adsorption with activated carbon is usually accomplished at pH values below 9.0, because alkalies sometimes react with odorous substances to form salts which are quite difficult to adsorb. Phenol is a specific example, since sodium phenolate can be formed at pH values above 9.0. Carbon surfaces should never be made alkaline, therefore, it must never be mixed with alkaline materials such as lime or soda ash. Although carbon and lime can be fed to the same point of application, they should not come in contact beforehand.

Special consideration must be given to the influence of chlorine and carbon together. Chlorine bearing compounds and carbon should never be mixed together in a dry state, because the chemical reaction can be sufficiently violent to cause an explosion. This reaction does not take place in water, so that chlorine and carbon *can* be applied at the same point of application. It is very desirable, however, to separate the points of application by at least 5 and preferably 15 minutes, because carbon tends to adsorb chlorine thus curtailing the effectiveness of both chemicals. In a few instances, carbon should follow the chlorine, but in the majority of cases carbon should precede the chlorine. One reason for this order is that chlorinated compounds are usually more difficult to adsorb with carbon.

A further advantage to feeding carbon first is that it can adsorb organic compounds, which are responsible for chlorine demand, and thus lighten the load for chlorine. Actual tests have demonstrated that the same residual can be carried through the plant with 25 to 40 per cent less applied chlorine. Although savings in chlorine do not pay for the carbon, the treatment costs where carbon is required can be very substantial. Many of the existing treatment plants do not have the physical set-up to separate the points of application, but it is hoped that designing engineers will make suitable provisions in new treatment plants.

Determining Carbon Dosage

In many cases, particularly where suitable laboratory facilities are not available, the carbon dosage is determined in actual plant practice by "hit-and-miss" methods. This can frequently result in over- or under-dosage. Fortunately, over-dosing with activated carbon can have no ill effect other than on the pocketbook, because it acts on physical rather than chemical principles. Where costs are of prime consideration, scientific methods are recommended.

In the laboratory, the "Threshold Odor Test" is very successfully used in determining the carbon dosage. The first consideration is to know the extent to which odors must be removed in order that a palatable water can be delivered. For this purpose, a taste and odor panel of personnel is recommended, consisting of at least four individuals. Samples of raw water should be chlorinated sufficiently to make the water safe for testing purposes, and then dechlorinated to avoid interference by chlorinous odors. This water can then be filtered and diluted with varying amounts of odor-free water for tasting purposes. That sample having the least dilution of odor-free water, which is pronounced acceptable by all four tasters, can usually be considered as the palatable limit. A threshold odor test can then be conducted on this sample, and the threshold number will represent the value which must be attained in actual practice.

Having determined the palatable

level, samples of water should then be treated with varying amounts of activated carbon. A sample should be collected at a point just prior to any carbon application. If carbon is not being used, a sample of raw water can be collected. To various samples, not to exceed four in number, different dosages of activated carbon should be added. For example, 2, 4, 8 and 16 ppm. If odor concentration is considered to be rather high, it would be desirable to use higher carbon dosages than suggested above.

After addition of the proper carbon dosage, each sample should be treated exactly the same as the existing treatment in the purification plant; this will include alum, lime, chlorine, etc. Contact times should parallel as closely as possible actual detention times in the plant. Samples are finally filtered, preferably through glass wool as the filter medium. This glass wool and all receptacles should be thoroughly rinsed with odor-free water to assure that extraneous odors are not added to any of the samples.

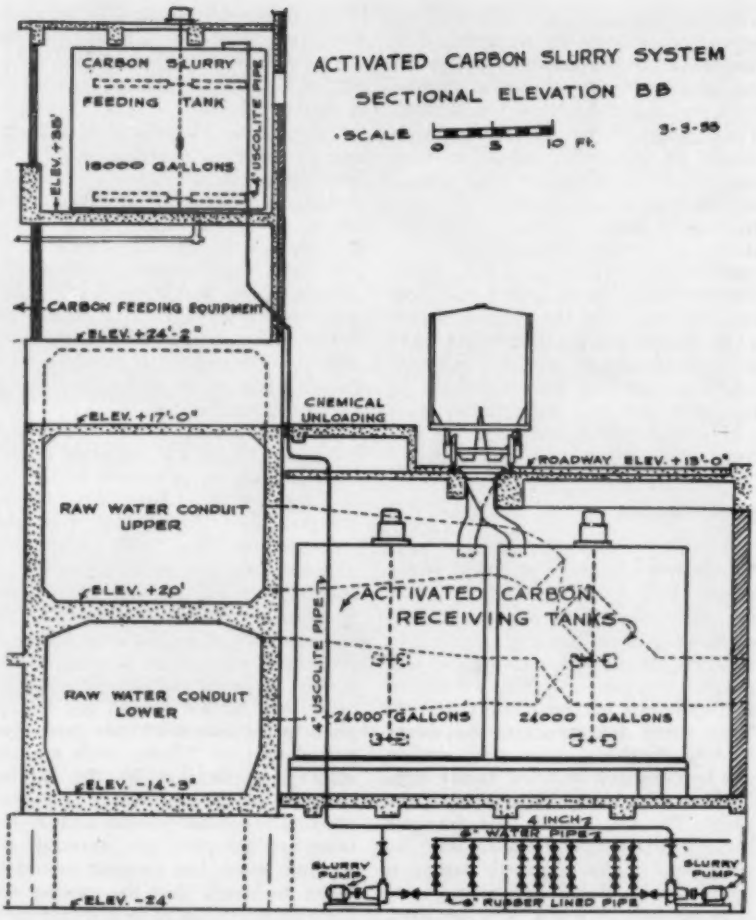
Finally, these treated samples and also a sample of the raw water should be evaluated for threshold odor number in accordance with the procedure in 'Standard Methods." Results obtained should be plotted on arithmetic graph paper and the curve drawn as accurately as possible to conform to the plotted points. From this curve, it should be possible to determine the carbon dosage necessary to produce the threshold number previously determined as acceptable for a palatable water.

In transposing these results to actual plant practice, it should be borne in mind that activated carbon accomplishes better results in plant practice than in small scale laboratory tests. *Therefore, it is desirable that the dosage determined in the laboratory should be cut in half for the first plant test.* Usually it will be found that half the laboratory dosage will give the desired results in plant practice. Some exceptions to this generalization have been encountered so that the final plant dosage may have to be increased or decreased to give optimum results. For example, if it is found that a laboratory dosage of 12 ppm of activated carbon is necessary to reach the palatable level, only 6 ppm should be employed in the first plant scale test. Based on results obtained in the plant, it may be necessary to revise the carbon dosage to as low as 4 ppm. or perhaps as high as 8 or 10 ppm. Such relations, once developed between laboratory and plant results, can usually be utilized on a basis for any subsequent tests and dosages.

Unfortunately, it is not possible to set any hard and fast rule as to the amount of carbon necessary, even though the threshold number of the raw water is known. For example, in some plants it has been found that one part per million of carbon is necessary for each threshold odor unit to accomplish palatability. Yet, in other parts of the country, this ratio may be one part of carbon for every three or four threshold odor units.

The type of odorous compound is also a contributing factor to this ratio. Therefore, if the type of odor changes suddenly, it is desirable to conduct another evaluation in order to determine the necessary carbon dosage. The reason for this is that some compounds may be easier or more difficult to adsorb by carbon. Also it should be borne in mind that as odor intensities increase carbon dosages may have to be greatly increased. In other words, if the odor concentration suddenly doubles, it may be necessary to use three times as much carbon in order to remove the objectionable odors. In any case, laboratory tests can constitute a very valuable guide in determining the optimum carbon dosage for plant scale use, always bearing in mind the relation between laboratory and plant results.

In actual plant operation, carbon dosages used will vary from as low as 2 lb per mil gal to as high as 1000 lb per mil gal. Extremely high dosages such as 500 lb per mil gal or more are rather rare and, fortunately, are usually of only very short duration. Although costs of treatment during these short periods of time would seem to be enormous, the average cost over the year is usually found to be very reasonable. If the total carbon costs are calculated on a per capita per year basis, it will be found that the annual cost is very nominal.

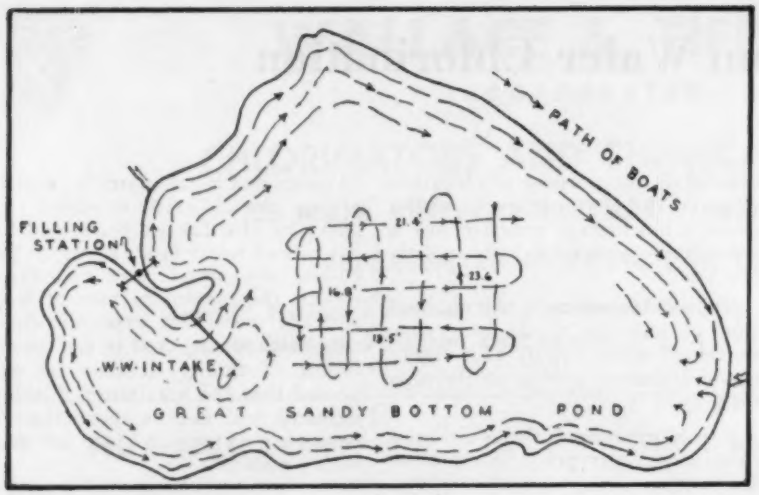


Courtesy of J. R. Baylis

DIAGRAM of handling and storage facilities for activated carbon slurry at Chicago, Ill.

Reservoir Application

Difficulties with unpalatable water unfortunately do not limit themselves



Courtesy H. E. Bailey & J. Studley

RESERVOIR treatment by boat
Course of boats for 108 acre, 300 mil gal reservoir

to systems where water purification facilities exist. Unfiltered reservoir supplies are perhaps even more likely to have odor difficulties, particularly of the algae type, because the water must be clear in order to be suitable for delivery to the public. Since algae thrive more particularly in clear waters, impounded supplies must always face this problem.

Since activated carbon is a fine black powder which will give a black turbidity to water, it is desirable that treatment be conducted so that little or no carbon reaches the distribution system. The general practice is to treat reservoirs with activated carbon so that no carbon is applied at any point near the reservoir intake. Thus the carbon particles have an opportunity to settle from the water, and any small amount that might get into the distribution system would not be noticeable to the consumer.

In some instances, carbon has been applied to reservoirs without regard to the proximity of the intake. Under these circumstances, the dosage of carbon is usually kept at a minimum of say approximately 1 ppm so that the small amount of carbon that would get through would not be sufficient to constitute consumer complaints. If the first treatment is insufficient to produce palatable water, further treatments can be made at weekly intervals until the difficulty is corrected and without any serious objections from the consumer.

In the actual application of carbon, the usual practice is to apply it in slurry form. This slurry form of carbon is applied to the reservoir on much the same principle as copper sulfate. However, in the case of carbon, higher dosages should be applied in the deeper areas so that the carbon concentration in the water is distributed as uniformly as possible, throughout the entire depth at points varying in depth.

Preparing the carbon slurry can constitute a problem unless proper equipment is available. An excellent method was worked out by Howard E. Bailey and James B. Studley for applying carbon to a reservoir at Pembroke, Mass. (See "Activated Carbon Treatment of an Open Reservoir", *Water & Sewage Works*, page 21, June 1947). In this particular case, arrangements were made to prepare a carbon slurry on the shore of the pond. This slurry was then piped to the water's edge where the boat could come in for charging. A drum in the boat was used to hold the carbon slurry from which it was discharged to the reservoir. Complete details are described in the article.

Another procedure was utilized by Fred Luthy of Orange, New Jersey. A boat was equipped with a gasoline motor and pump, and a 50 gal steel drum for the carbon slurry. Bags of carbon were loaded aboard the boat for wetting. The pump served to supply water to the drum where the carbon slurry was prepared, and the pump also served to force the carbon slurry under pressure through a hose for distribution to the surface of the reservoir. Complete details of this arrangement are included in an article entitled, "Powdered Activated Carbon Application to Orange Reservoir"—September, 1950 issue *Taste and Odor Control Journal*.

Based on the small concentrations of carbon utilized thus far in reservoir applications with successful results, there seems reason to believe that this method of treatment constitutes a very efficient procedure. Generally speaking, dosages used are in the very low ranges normally used in water treatment plants. Yet, the production of a palatable water from a very severe odor condition has been the result very consistently. There is also the possibility that the carbon which settles out at the bottom of the reservoir can still accomplish beneficial results. The carbon will still have some reserve capacity for odor adsorption, and it may act toward stabilizing any decomposition odors which might normally develop at the reservoir bottom.

Blackout of Algae

In addition to foods normally present in water, algae requires sunlight and suitable temperatures for propagation. The fact that activated carbon gives a dark appearance to water was considered as a possibility for eliminating the sunlight. In the application of activated carbon for this purpose, the carbon is thoroughly wet and applied as a slurry to the entire surface of the body of water to be treated. For successful results, application is made once or twice each day during periods favorable to algae growths. Thus application is usually limited to the summer months and also only to days of prolonged sunlight. Naturally, during cloudy days, carbon application is not necessary.

It remained for Hartung and Lischer of the St. Louis County Water Department, St. Louis, Missouri, to determine the necessary carbon dosage to treat a particular water surface. Based on their studies, it was found that a dosage of approximately a quarter of a pound of carbon would successfully black out a water surface of 1,000 sq ft. Thus it must be realized that the dosage necessary for carbon blackout is usually far below that necessary for accomplishing taste and odor control. However, if carbon is necessary for correction of odors, the amount used for algae blackout would automatically reduce the quantity of carbon necessary for eliminating odor conditions.

Studies in the field have shown activated carbon to be the most universally successful answer to taste and odor problems. Some reported failures have been due to improper point of application or an attempt to accomplish results with too small a dosage. It is safe to state that practically all odors can be reduced to a palatable level with activated carbon if a sufficient quantity is used at the proper point of application.

Notes on Water Chlorination

THE USE of chlorine as a disinfectant is so widely established that the term "chlorination" frequently is used to mean disinfection but chlorine has other uses as well.

Chlorine is an extremely active chemical, prepared by the electrolysis of salt brine. It is purified, dried, liquefied by compression and cooling, and loaded into 105 or 150 lb. cylinders, ton containers or tank cars for shipment to consumers. The handling, use, and safety factors in chlorination practices have been discussed elsewhere in the Reference and Data Edition of *Water & Sewage Works.*

Purpose of Water Chlorination

Chlorine is added to water to destroy pathogenic and other bacteria. Chlorination is also used for taste and odor control, for chlorination of transmission mains to maintain carrying capacity, and to control slime growth in process and cooling water systems.

Types of Chlorination

When chlorine added to water has satisfied the chlorine demand, a residual is obtained. In the presence of ammonium compounds, either natural or added, chloramines are produced and may be measured as "combined residual chlorine." The treatment is known as "combined residual chlorination." If additional chlorine is added to pass the "breakpoint" (at which point combined chlorine residuals disappear), "free residual chlorine" is produced and the treatment is known as "free residual chlorination." Disinfection is more effective in the presence of "free residual chlorine," but this treatment requires greater chlorine dosage capacity than combined residual chlorination.

For some conditions, it may be advisable to add chlorine in amounts above that necessary to produce a nominal free chlorine residual. The excess is obtained by "super-chlorination" and the excess must be destroyed by subsequent "dechlorination," with sulphur dioxide, sodium sulfite, sodium thiosulfate or activated carbon.

Points of Application

Selection of application points depend on the purpose of chlorination and the physical layout of the plant. Chlorination practice has a terminology associated with application points.

Plain chlorination is the application of chlorine to an otherwise untreated water supply as it enters the distribution system or the pipe leading to it.

Prechlorination is the addition of chlorine to water **prior** to any other treatment.

Post-chlorination is the addition of chlorine **subsequent** to any other treatment.

Re-chlorination is the application of chlorine to water at one or more points in the distribution system following previous chlorination treatment.

Chlorination Capacity

The amount of chlorine used in water treatment at a plant is usually expressed in terms of pounds per day and chlorine feeders are calibrated in units of pounds per day. The amount of chlorine required for proper disinfection, or other use, depends on the chlorine demand of the water, (expressed in ppm), the flow of water (in mgd), the amount and kind of chlorine residual desired, and the contact time.

Chlorine demand is defined as the difference between the amount of chlorine added and the residual obtained under standard specified conditions. Chlorine demand is determined by standardized techniques as given in the 10th Edition of "Standard Methods for Water and Sewage Analysis." Chlorine demand depends on impurities present in the water, temperature and contact time.

Residual chlorine is defined as the amount of free or combined chlorine remaining after the chlorine demand has been satisfied. It is determined by standardized techniques, using ortho-tolodine or orthe-tolidine-arsenite reagents, or by amperometric titration.

The chlorine dosage required is the sum of the chlorine demand and the chlorine residual desired. It is expressed, usually in pounds per 24 hours and is calculated by multiplying the chlorine demand (in ppm) by the factor 8.34, and by the rate of water flow (in mgd). To choose the proper size chlorine feeder, the maximum rate of flow and the maximum expected chlorine demand are used in the calculation. Normally, it may be expected that the maximum chlorine demand will not be more than 2 ppm, in waters which are not highly polluted.

Chlorine Feeder Control

The feeding of chlorine gas by machines designed for that purpose may be controlled in one of four ways: (1) Manual control, wherein start, stop and rate of feed is set manually; (2) Semi-automatic control wherein the feeder starts or stops automatically with a pump or timer control and operation is at a manually pre-set rate (this system includes "step" operation); (3) Program control wherein the chlorine feed rate is automatically changed throughout the day according to a predetermined schedule; (4) Proportional pacing control wherein the equipment automatically adjusts the chlorine feed rate to provide a constant preestablished dosage regardless of the rate of flow of the water.

Types of Feeders

Chlorine feeder devices may be either vacuum-type, partial vacuum-type, partial vacuum type, pressure type, or pulsating type. Chlorine may be delivered either as a solution or as a direct feed to one or more points of application, (solution feed is most common in water treatment).

The installation of chlorine feed equipment should consider point of application, accessibility of feeder location, space requirement heating facilities and safety conditions.

Treatment

Control of chlorination best accomplished by chlorine residual tests, feed adjustments according to chlorine dosage nomograms, and bacteriological tests for confirmation of disinfection results.

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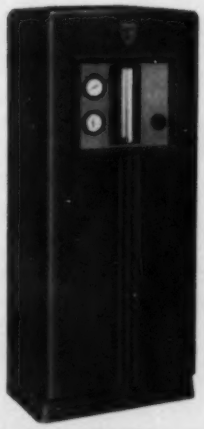
W&T Series A-711 V-notch Chlorinator

The W&T Series A-711 Chlorinator features a new concept in chlorine flow control—the V-notch Variable-Orifice. This provides wide range adjustment and excellent reproducibility of chlorine flow with substantially linear flow readings on a rotameter feed rate indicator. The Series A-711 Chlorinator is adaptable to any type of chlorinator control. Corrosion resistant materials, which include fiberglass plastic for the chlorinator cabinet, are used throughout to assure long life and maintenance free operation.



W&T Series A-711 V-notch Chlorinator

W&T DIAPHRAGM PUMPS

W&T Diaphragm Pump

Chlorination of small water supplies involves problems which W&T Diaphragm Pumps are especially designed to meet. This equipment feeds hypochlorite solutions or other soluble treatment chemicals, and is furnished in three types:

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day.

Automatic Water Operated Diaphragm Pumps automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

WT SILACTOR®

The WT Silactor (pronounced SILL-actor) provides a system for the continuous production of activated silica with chlorine. Raw materials—chlorine and sodium silicate—are withdrawn directly from their own containers without handling or dilution. All chlorine used in the WT Silactor is available for the normal functions of chlorine, such as killing bacteria and algae, or for the oxidation of iron, manganese and other oxidizable material.

WT Silactor

DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. Both volumetric and gravimetric weighbelt types are available. Dry feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from ounces per hour to 3000 pounds per minute, depending upon the equipment and chemical used.

CONVENIENCE

W&T is represented by a service staff prepared to discuss the proper equipment for any chlorination problem.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

HOW TO CALCULATE CHLORINE COST*

Many prospective users of chlorine are often confused by the many forms in which chlorine may be obtained. They often become entangled in reams of figures and formulae when they attempt to figure probable chemical cost for chlorine in any one of its three principal forms; gas, calcium hypochlorite powders and sodium hypochlorite solutions. Shown here is a method for making the cost comparison.

First, it should be remembered—*One pound of Available Chlorine is the same as one pound of dry chlorine gas. When one pound of dry chlorine gas is put in solution it produces one pound of available chlorine.*

The chart shows that one pound of available chlorine is contained in one pound of chlorine gas; that one pound of available chlorine is contained in 1.43 pounds of dry high test calcium hypochlorite powder (70% available chlorine by weight); that one pound of available chlorine is contained in varying liquid volumes of sodium hypochlorite solution according to its specified "percent available chlorine by volume".

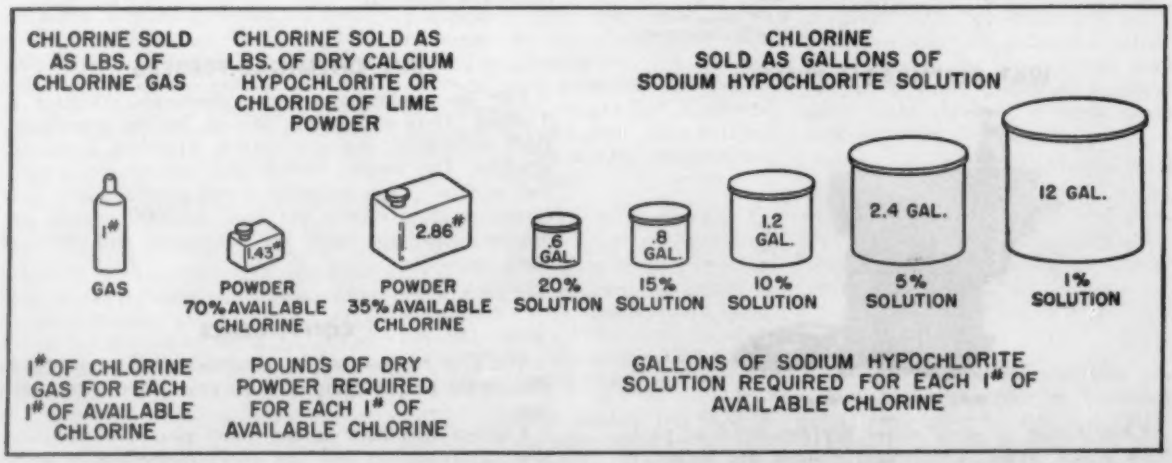
The prospective user can figure his probable costs from the figures given here following a telephone call to his nearest supplier. First of all, he must know approximately how many lbs. of chlorine he will require per 24-hr. day. Armed with this figure, in plain lbs., his nearest supplier will give him the delivered price: of chlorine, in cylinders per pound of chlorine; of dry calcium hypochlorite powder, per pound of powder having a specified per cent available chlorine content per pound of powder; and of sodium hypochlorite solution, per gallon of solution having a guaranteed percent available chlorine by volume. (The anticipated quantity to be used per 24-hr. day will govern the container sizes and to some extent the cost.)

As an example:—

1. We will require approximately 100 lbs. of chlorine per 24-hr. day.
2. From a call to our supplier we get the following figures:
   a. Chlorine Gas in 150# cylinders, delivered at 11.25c/lb.
   b. High test calcium hypochlorite dry powder, 70% available chlorine by weight, in 100# drums delivered at $32.50/drum, or 32.5c/lb.
   c. Sodium hypochlorite, 15% available chlorine by volume, delivered in 1000-gal. lots at 24c/gal.
3. Now some simple mathematics gives us our anticipated cost per 24-hr. day for chlorine in each of its available forms:
   a. 100 lbs. of Chlorine Gas will be required for 100 lbs. of available chlorine and will cost us—
      100 lbs./day x 11.25c/lb. . .$11.25/day
   b. Calcium Hypochlorite powder will require 100 lbs. x 1.43 (from chart) or 143 lbs. of dry Calcium hypochlorite powder to provide 100 lbs. of available chlorine and will cost us—
      143 lbs./day x 32.5c/lb. . .$46.48/day
   c. Sodium hypochlorite solution will require 100 lbs x 0.8 gals. (from chart) or 80 gals. of 15% solution to obtain 100 lbs. of available chlorine and will cost us—
      80 gal./day x 24c/gal. $19.20/day

These calculations present the basic economics of chlorine in each of its commercial forms. Before a final decision is reached the prospective user should investigate feeding equipment costs and the form in which the chlorine required is the most usable for his particular application.

Reprinted from Chlorination Topics published by Wallace & Tiernan, Inc.


CHLORINE SOLD AS LBS. OF CHLORINE GAS
CHLORINE SOLD AS LBS. OF DRY CALCIUM HYPOCHLORITE OR CHLORIDE OF LIME POWDER
CHLORINE SOLD AS GALLONS OF SODIUM HYPOCHLORITE SOLUTION
1#
1.43#
2.86#
.6 GAL.
.8 GAL.
1.2 GAL.
2.4 GAL.
12 GAL.
GAS
POWDER 70% AVAILABLE CHLORINE
POWDER 35% AVAILABLE CHLORINE
20% SOLUTION
15% SOLUTION
10% SOLUTION
5% SOLUTION
1% SOLUTION
1# OF CHLORINE GAS FOR EACH 1# OF AVAILABLE CHLORINE
POUNDS OF DRY POWDER REQUIRED FOR EACH 1# OF AVAILABLE CHLORINE
GALLONS OF SODIUM HYPOCHLORITE SOLUTION REQUIRED FOR EACH 1# OF AVAILABLE CHLORINE

COMPARATIVE CHART showing amounts of material required to provide one pound of available chlorine

CHLORINE the green goddess

觀世音

To the Buddhist, Kuan Yin is the goddess of mercy. To the chemist, this green goddess symbolizes chlorine — one of the most widely useful of all elements. Purifier, oxidant, bleach, extracting agent, its uses range from papermaking to ore reduction, from foodstuffs to insecticides, through scores of chemical and industrial processes. Its source, to many users throughout Mid-America, is Frontier Chemical Company . . . where salt brine is electrolyzed to produce chlorine that consistently exceeds 99.9% purity. From Wichita, Kansas, Frontier offers fast shipments by rail in 16, 30 and 55-ton tank cars and multi-unit cars of one-ton containers. From both Wichita and Denver City, Texas, Frontier also delivers by truck in one-ton containers. Frontier chlorine is tailored to your specifications for: Purity • Dryness • Accurate weight loading • Unloading convenience • Prompt shipment • Controlled quality. We are at your service.

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(14 and 36 gamma)

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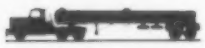

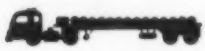

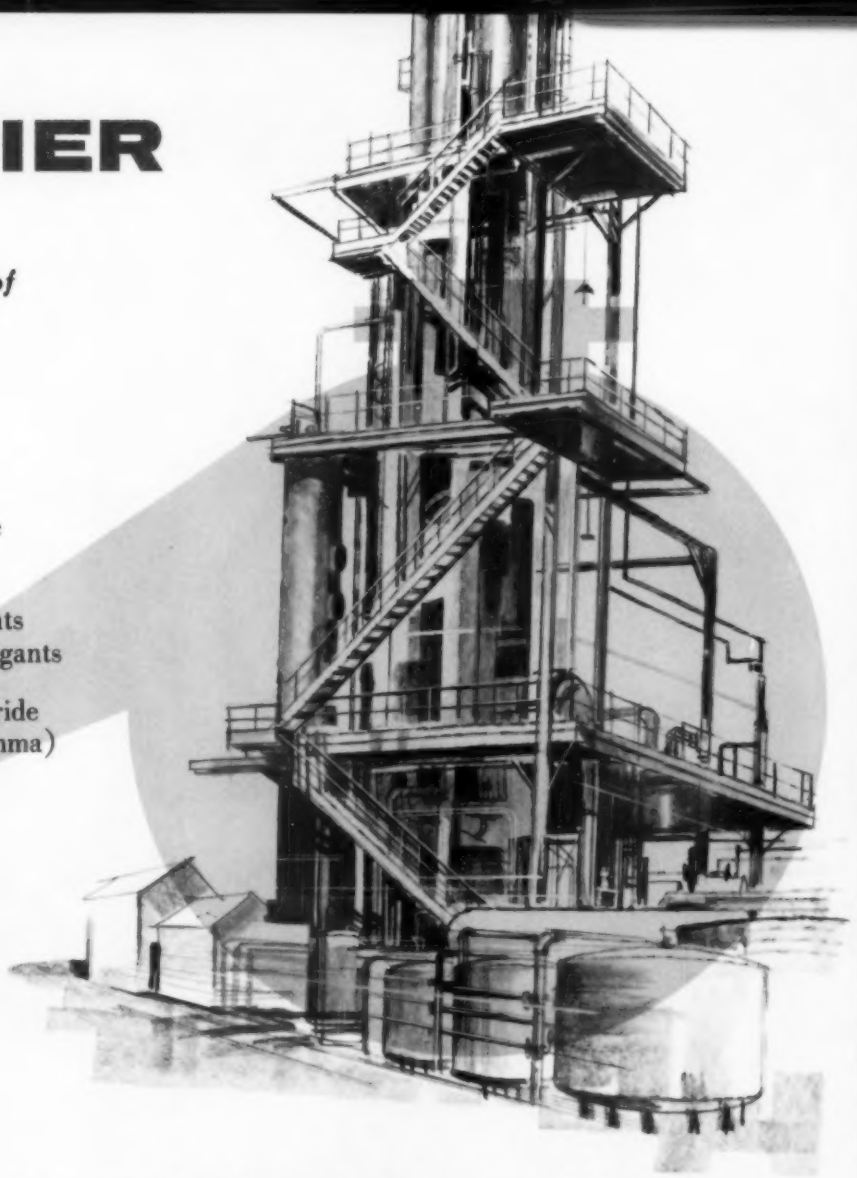

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Safe Practices in Chlorine Handling

From a Report
by
THE JOINT COMMITTEE ON CHLORINE SUPPLY

IT IS ESSENTIAL for persons responsible for the handling and application of chlorine at any installation to have a relatively comprehensive knowledge of the characteristics and properties of chlorine.

GENERAL RECOMMENDATIONS:

1. Only reliable men whose training in the handling of chlorine is commensurate with their responsibilities should be permitted to handle chlorine.

2. Chlorine and chlorinator rooms should be provided with adequate ventilation. In large installations, subsurface installations, or in buildings occupied by persons or containing equipment subject to chlorine attack, a separate and reasonably gas-tight room, equipped with mechanical ventilation which will change the air twice every minute, is considered essential and is required by some local and state regulations. Exhaust duct ports should be at floor level and ducts should terminate through a completely separate exhaust system to a location high enough to insure atmospheric dilution without endangering personnel or adversely affecting property in the area. Air inlets should be located across the room from exhaust ports, with the air of such temperature that it will not affect the chlorination equipment adversely.

Shutoff valves should be provided near chlorinators if the connected chlorine containers are in a separate room or a considerable distance from the chlorinators. Switches for fans and lights should be outside the room, at the entrance. The vent hose for the chlorinator should discharge to the outside atmosphere, above grade.

3. A suitable number of gas masks of types approved by the United States Bureau of Mines for chlorine should be provided and persons employed in the handling of chlorine should be trained in the use and maintenance of the masks. Gas masks should be located outside the probable area of contamination so that it will be possible to reach them in case of emergency. Where chlorine is used over wide areas masks should be available in several locations.

4. To test for chlorine leaks. Attach a cloth to one end of a stick, soak the cloth with ammonia-water, and apply to the suspected area. A white cloud of ammonium chloride will result if there is any leakage.

5. As soon as there is any indication of the presence of chlorine in the air, steps should be taken to correct the condition. Chlorine leaks always get worse if they are not corrected promptly. Solvay Emergency Devices, Kits "A," "B" or "C" should be available for stopping leaks in chlorine containers and men should be trained in the use of such emergency equipment. Telephone your chlorine supplier or any chlorine producer if you need help. Always wear a gas mask when correcting chlorine leaks. If a chlorine container is leaking in such a position that chlorine is escaping as liquid, the container should be turned so that chlorine gas escapes. The quantity of chlorine escaping from a gas leak is about one-fifteenth the amount that escapes from a liquid leak through the same size hole. At regular points of storage and use, emergency preparations should be made for disposing of chlorine from leaking cylinders or ton containers. Chlorine may be absorbed in caustic soda, soda ash, or hydrated lime solution. Caustic soda is recommended as it absorbs chlorine most readily. The proportions of alkali and water preferred for this purpose are given in the following table:

RECOMMENDED ALKALINE SOLUTIONS FOR ABSORBING CHLORINE

Chlorine Container Lbs. Net	Caustic Soda Lbs. Chem.	Caustic Soda Gals. Water	Soda Ash Lbs. Chem.	Soda Ash Gals. Water	Hydr. Lime* Lbs. Chem.	Hydr. Lime* Gals. Water
100	125	40	300	100	125	125
150	188	60	450	150	188	188
2000	2500	800	6000	2000	2500	2500

* Hydrated lime suspension must be continuously agitated with vigor while chlorine is being absorbed.

6. Containers should be stored at a moderate temperature. Flames or direct heat should never be applied to a container. Chlorine containers connected to apparaus should be protected from a temperature higher than that of the equipment. When a number of containers are connected to the same manifold, chlorine may go from the warmer containers to the colder ones, which could result in filling some above the safe limit. The heating of containers involves danger because the fusible plugs are designed to soften or melt at a temperature between 158° and 165°F. At temperatures above 180°F, dry chlorine will attack the steel of the cylinders.

7. Avoid dropping or bumping chlorine containers. Containers should be securely fastened to prevent tipping or rolling.

8. Valve protection hoods on clyinder and ton containers should always be kept in place except when such are being emptied. Never hoist cylinders by the hood.

9. Keep valves of cylinders and ton containers closed at all times when not in service.

10. Store full and empty cylinders and ton containers in different places to avoid confusion. It is good practice to tag empties.

11. Put cylinders or ton containers in service in the order in which they are received. Cylinders and ton containers in active use should be located on a scale, so that the operator may know at all times the amount of chlorine in the cylinder or ton container, and also for purpose of recording chlorine used.

12. Use nothing but approved fitting for connecting chlorine containers. Never use pipe fittings on chlorine valves.

13. The following first aid measures are recommended for persons exposed to chlorine:

First Aid, 1. Carry patient from gas area. Patient should preferably be kept in a warm room (about 70 degrees Fahrenheit). Supply blankets if necessary. Keep patient warm and quiet. Rest is essential.

First Aid, 2. Place patient on back with head and back elevated.

First Aid, 3. *Call a physician immediately.*

First Aid, 4. Splashes of liquid chlorine and chlorinated water destroy clothing, and if such clothing is next to the skin will provide irritation and acid burns. In such cases remove clothes and keep patient warm with blankets.

First Aid, 5. A carbon dioxide and oxygen mixture with not to exceed 7 per cent of carbon dioxide may be given. This mixture, ready prepared, and sold with the necessary apparatus, can be administered intermittently for periods of two minutes followed by two-minute rest periods over a total period not to exceed thirty minutes. Instructions of the purveyor of the gas apparatus should be carefully followed. If a carbon dioxide and oxygen mixture is not readily available, oxygen alone may be used.

First Aid, 6. Milk may be given in mild cases as a relief from throat irritation.

First Aid, 7. If breathing has apparently ceased, start immediately the back pressure-arm lift method of resuscitation.

First Aid, 8. Provide First Aid as may have been prescribed by the physician pending his arrival.

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The available chlorine in HTH is in the form of true calcium hypochlorite, which is $Ca(OCl)_2$. When consideration is given to the light-weight, non-returnable containers in which HTH is shipped, its available chlorine per pound of gross weight exceeds that of liquid chlorine in the 100- and 150-lb. cylinders. Moreover, its use involves none of the hazards that attend the handling and use of liquid chlorine. It is little wonder, therefore, that water works men avail themselves of this convenient, safe source of available chlorine wherever practicable.

The 5-lb. cans of HTH Granular, packed 9 to the case, are particularly convenient for sanitization of newly laid pipelines, isolated water supplies and at locations where transportation of the chlorine carrier is a troublesome factor. For continuous or emergency hypochlorination of water supplies, the 100-lb. drum of HTH Granular may be a more economical unit. In determining the more desirable package, however, consideration should be given to the advantage of keeping a product not immediately needed in sealed 5-lb. cans rather than in a 100-lb. drum that is frequently opened.

SODIUM CHLORITE

Chlorine dioxide (ClO_2) is produced at the point of use by the interaction of chlorine and sodium chlorite ($NaClO_2$). The reaction takes place in a simple mixing chamber or solution generator, and the reagents may be (1) solutions of chlorine and sodium chlorite or (2) solutions of HTH, acid and sodium chlorite. The dilute chlorine dioxide solution thus formed is fed directly into the water for taste and odor control and for disinfection.

Mathieson Sodium Chlorite Technical is a dry, flaked material containing 130 per cent available chlorine. It is non-hygroscopic, extremely soluble in water and very stable both in dry form and in solution. Packed in 100-lb. drums and 25-lb. pails.

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For convenient handling in many water treatment applications, HTH is also available as HTH Tablets. This product is simply HTH in the form of compressed, easy-to-handle tablets which dissolve slowly and provide a continuous source of available chlorine over an extended period of time.

HTH Tablets are made wholly of dependable HTH and contain 70% available chlorine—the same as the time-tested granular product, HTH Granular. The tablets are stable and dust-free and thus offer an exceptionally safe and convenient means of handling, measuring and storing available chlorine. HTH Tablets are packed in 100-lb. drums and in cases of twelve 3¾-lb. cans.

For your protection every genuine HTH Tablet is stamped HTH.

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Activated Alum—the only alum designed exclusively for use in the field of water and sewage treatment—contains finely ground natural silicates, providing a free-flowing, less hygroscopic product of porous structure and higher alumina content. Activated Alum is used and preferred by some of the largest municipal water works in the U.S.A. Packed in 100-lb. multi-wall paper bags.

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Chlorination with Hypochlorites

by V. W. LANGWORTHY

Chief Applications Engineer
Omega Machine Co., Div. of B-I-F Industries, Inc., Providence, R. I.

CALCIUM and sodium hypochlorites, often referred to as bleaches, have long been established in the sanitary field as sources of chlorine. The true calcium hypochlorite is particularly useful in this field, due to its concentrated form and ease of handling. It has not been possible to produce sodium hypochlorite as a stable powder, thus its use in the treatment of water and waste is somewhat limited. The uses and handling of these hypochlorites, together with the equipment commonly used in applying them, will be reviewed in this discussion.

Calcium Hypochlorite

Manufacturing techniques have advanced to the point where a relatively stable calcium hypochlorite containing 70 per cent available chlorine is produced. It is important to plant operators that the available chlorine content of successive shipments can be depended upon, with no major changes being required in pump settings or for preparing stock solutions.

Granular in texture, today's calcium hypochlorite is a dry white powder having a minimum of dusty fines. Reduction in caking tendencies has been accomplished by holding the calcium chloride concentration to a minimum. Stored in a dry atmosphere and kept in covered containers, lumping may be avoided.

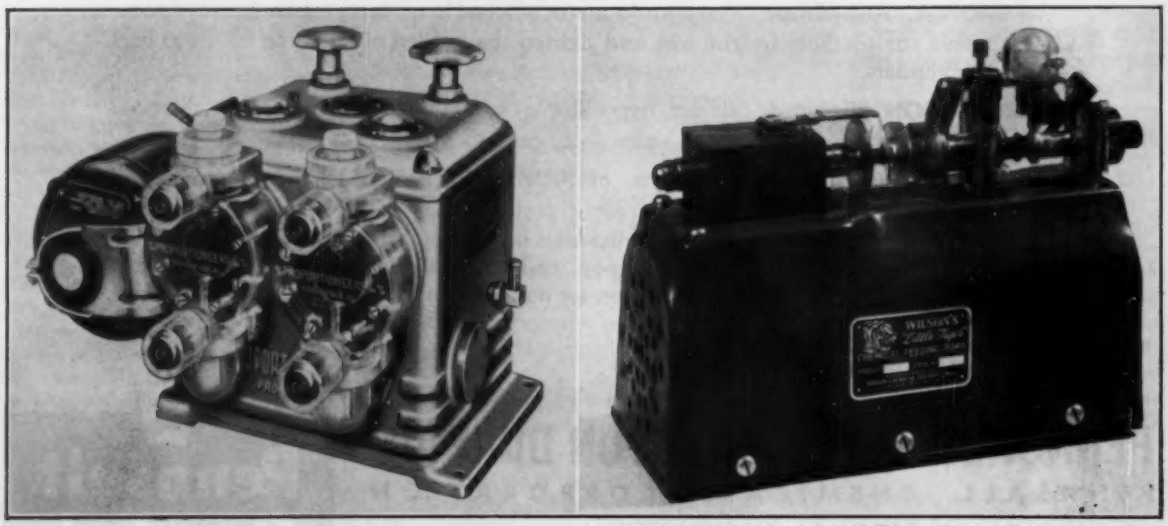
Five pound, re-sealable cans and one-hundred pound drums are the package units generally found convenient by sanitation users. It should be noted that the one-hundred pound drum is suitable for larger continuous users, while the five pound can should be specified where all of the contents will not be used immediately after opening.

Calcium hypochlorite, generally termed "high test" hypochlorite, may be utilized to serve any and all of the functions of gaseous chlorine, including disinfection, odor control, BOD reduction, control of sludge bulking, main sterilization, industrial waste oxidation and swimming pool sanitation. It is a product capable of providing readily available chlorine for emergency situations, even in large water and waste treatment plants.

Handling Calcium Hypochlorite

Calcium hypochlorite is termed "relatively stable" because it is a highly active compound. Its activity creates a serious problem for the manufacturer: to produce a compound with maximum reactivity, yet one which will remain stable throughout production, packing, distribution and storage. It could be assumed that product deterioration will begin as soon as the packing operation is completed, yet the facts are that storage at 86° F for one year will reduce the available chlorine only 10 percent of that originally present. Cooler storage temperatures decrease even this small loss[1].

There is a problem involved in selecting the proper storage place for this useful and powerful chemical. Certainly, in the interests of preserving purchased available chlorine, low storage temperatures are indicated. While relatively stable under normal atmospheric conditions, reaction may occur spontaneously between hypochlorite and such organic substances as turpentine, ether, oils, sugar, fats and other oxidizable materials. For this reason implements, such as scoops, should be clean and dry when handling calcium hypochlorite. It also follows that the storage location should be well away from all combustible material. Rubber gloves and



Proportioneers, Inc., and Wilson Chemical Feeders, Inc., Photos

HYPOCHLORITE solution feeders of the positive displacement type

Fig. 1 (left) is a diaphragm type feeder which may be used to dispense two separate solutions or, by manifolding the discharge ports, one solution at double capacity. Fig. 2 (right) is a plunger type feeder.

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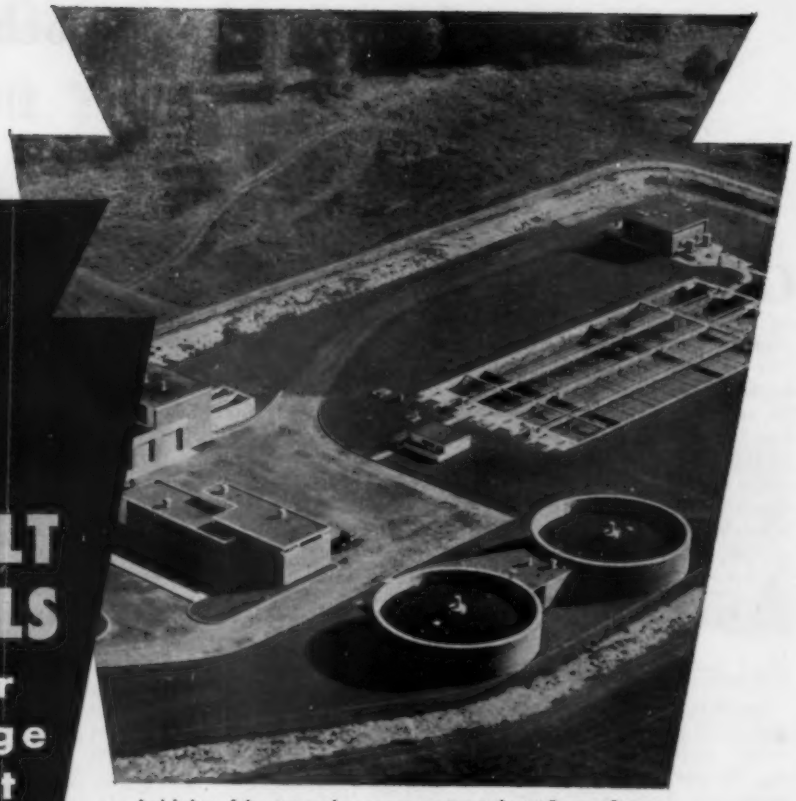

Aerial view of the new, modern sewage treatment plant at Eugene, Oregon.

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protective aprons should be worn when preparing and handling solutions of hypochlorite for any purpose.

Feeding Calcium Hypochlorite

Feeders for applying hypochlorite solutions require less investment than gaseous chlorine dispensers, a condition favoring their use in smaller treatment works. No attempt will be made here to specify at what flow rates one material should be selected over another, since variables such as chlorine demand and local requirements considerably alter installation selections.

Calcium hypochlorite is readily soluble in water. It is possible, therefore, to prepare solutions of varying concentrations, depending on the dosage required and the desired frequency of preparation. As is true with all chlorine solutions, materials resistant to corrosive attack should be used. Wooden, ceramic, or suitably coated steel dissolving tanks, and specially constructed feeding devices, will contribute to a satisfactory installation requiring a minimum of maintenance. As the granular product is free flowing, it may temporarily be dispensed through suitable resistant dry feeding equipment.

Numerous types of feeding devices are available which may be adjusted manually for dosage control; or dosage may be automatically regulated proportional to the flow treated.

Feeding "Chlorinated Lime" and "Soda Bleach"

Commercial chloride of lime or, properly speaking, "chlorinated lime," is a dry white powder containing about 35 per cent available chlorine when fresh. When exposed to air, this material rapidly absorbs moisture, becomes gummy, and its chlorine content is reduced. As a result, standard strength solutions of chlorinated lime can be prepared only by making an analysis of each batch for available chlorine. Obviously, chlorinated lime cannot be dispensed by dry feed devices.

Sodium hypochlorite or "soda bleach" solutions commercially available usually contain about 15 per cent available chlorine. The excess alkali present makes these solutions relatively stable: fresh solutions stored in a cool, dark location should be stable for at least three months. The stock solution may be applied as such, or may be diluted, to feed a relatively fixed concentration of available chlorine.

For sanitation uses the stability and convenience of true calcium hypochlorite (the "high test" hypochlorite) makes it superior to chlorinated lime and soda bleach. Except for emergency use, or for some special local condition, chlorinated lime and soda bleach are now considered impractical or too costly as sources of water and waste treatment chlorine.

Solution Feed

Two general types of equipment for feeding hypochlorite solutions are available to the sanitary field: (1) Constant rate feeders, which require manual adjustment of rate, and (2) Proportional rate feeders, which automatically vary the delivery rate with changes in the flow being treated. Proper feeder selection depends on conditions existing at the point of application, including space requirements, water pressure conditions and supervision available[2].

Constant Rate Feeders

Delivery of hypochlorite solution at a fixed rate requires the attention of an operator to vary the dosage rate as a result of changes in water quality or flow rate at the point of application. The possibility of over or under chlorination exists, when feeding at a fixed rate, as a result of human error or insufficient sampling.

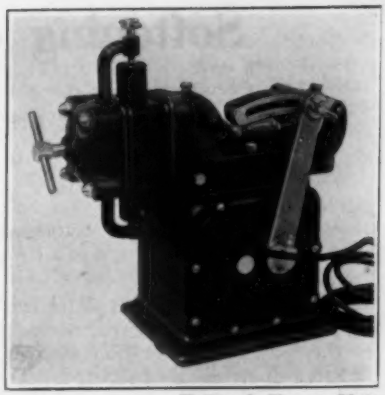
Feeders available for dosage at a constant rate usually are positive displacement, lowering orifice, or constant head orifice devices. Positive displacement units are either diaphragm (Fig. 1) or plunger (Fig. 2) type pumps, their pumping rate being a function of stroke frequency or stroke length.

Lowering orifice type devices are based on the constant level principle, with an open end hose or pipe connected at or near the bottom of the tank. As the open end is lowered, the solution flows to the point of application through the connection mentioned above.

Constant head orifice devices utilize the well-known constant level float valve which provides a constant head above a calibrated orifice.

Proportional Rate Feeders

The possibility of inaccurate chlorine dosage referred to earlier is materially reduced when the feeding equipment functions proportional to flow. It is possible to adapt all the above devices to proportional flow, with the exception of constant head orifice boxes.



Wallace & Tiernan Photo

HYPOCHLORITE feeder

Where disinfection is the primary purpose of hypochlorination, uninterrupted service is mandatory. Reliance usually is placed on the installation of duplicate equipment which would be available in event of mechanical failure of the apparatus in service. Interruptions due to electrical failure would indicate that hypochlorite dispensers in continuous service should be powered either hydraulically or mechanically.

Positive displacement pumps are available which are driven by water meters, no electricity being required for operation. In these units, the dosage rate is governed by water flow through the meter, thus automatically proportioning the treatment chemical. Where electric drive is permissible, the units may function proportional to flow by interconnecting with metering or pumping energy sources.

Lowering orifice type feeders may employ electric or spring driven clock mechanisms to lower the free end of the pipe or hose. Proportional flow will result if the electric current supply is tied in with metering or pumping equipment.

Booklets Available

Manufacturers of calcium hypochlorite have prepared for distribution booklets which describe in detail the uses for their product. Tabular data are included for use in disinfecting varying diameters and lengths of water mains, plus other valuable information.

References

(1) Logan, J. O. and Savell, W. L. "Calcium Hypochlorite in Water Purification", Jour. A. W. W. A., *32*:1517 (1940).

(2) Mathieson Chemical Corporation, "Hypochlorination of Water", Tech. Bulletin, 47 pages, Seventh Ed. (1951).

Softening of Municipal Water Supplies

With particular reference to its economic aspects

by WILLIAM W. AULTMAN

Vice President, James M. Montgomery, Consulting Engineers, Pasadena, Calif.

THE HARDNESS of a water supply is of special concern, not only to the individual domestic consumer, but more particularly to the commercial and industrial consumer. Hard water requires much soap to form a lather and more synthetic detergents to do proper cleaning. Hard water deposits sludges or incrustations on surfaces with which it comes in contact in vessels and boilers in which it is heated.

The householder judges a water to be hard if much soap is required in the bath to produce a lather, and soft if it lathers freely. The industrialist generally requires a specific quality of water for his process, and must condition the water to suit his needs if it is not already of satisfactory quality.

When is a water considered hard? The definition of a hard water is not precise. The recently published textbook by Fair and Geyer on "Water Supply and Waste-Water Disposal"[1] uses the definition generally accepted by water authorities. They say: "Waters containing less than 50 mg/l of hardness are considered soft; those containing more than 100 to 150 mg/l, the magnitude depending upon the regional composition of available water supplies, are considered hard." The designation mg/l means milligrams per liter, which is practically equivalent to parts per million (ppm), the term previously used to express the mineral concentration of solutions.

The substances responsible for hardness are calcium and magnesium ions and, to a lesser extent because of their normally smaller concentration, those of iron, manganese, strontium and aluminum.

Soap vs. Synthetic Detergent

With the advent of synthetic detergents the question that is asked is: "Why be concerned about softening hard water now that the synthetic detergents are replacing soap and the detergents work just as well in hard water as in soft?" The answer is that this statement is not correct. Also, the effect of water quality on the cleansing properties of soap or synthetic detergents is not the only consideration, for water quality affects many other factors that are of major importance.

The desirability of softening has been evaluated in the past primarily from the standpoint of obtaining a material saving in the cost of soap to the individual consumer. This factor has been used because it was one thing to which a dollar value could most readily be assigned. However, this is but one of the many ways that hard water costs the consumer more than does soft water. This will be discussed later.

A definition of terms is desirable. Detergents are a cleansing aid, soap being one of the oldest and best known detergents. The newer types of "soapless" soaps are called synthetic detergents or syndets. Soap is a sodium or potassium salt of fatty acid made by combining an alkali with a fat. Syndets are complex chemical compounds made from petroleum or fats or oils. Builders may be added to soaps or syndets to give them greater cleaning power and/or some water softening properties. These builders are alkalies, such as carbonates, silicates, and phosphates [2].

Both soaps and syndets may be divided into two groups: (a) the mild, and (b) the "built" product. Mild soaps are the pure neutral soaps generally used for washing fine fabrics and for the bath. Built soaps are for heavier laundry purposes. Likewise, there are the mild syndets used for washing fine fabrics, such as blouses, hose, lingerie, etc., and the built syndets for heavier laundry of sheets, towels, shirts, etc. The syndets may further be of the high-sudsing or low-sudsing types.

In using soap and water a blanket of suds indicates that sufficient soap is present to combine with the mineral hardness of the water, and also to provide cleaning power. With syndets, however, a blanket of suds may be produced before the amount of detergent added is sufficient to give maximum soil removal, or with certain types of syndets it is possible that little or no suds are formed at any dosage. Maximum soil removal refers to the level at which additional detergent does not increase the cleaning power appreciably.

The changing attitude of the syndet manufacturing chemists is shown by a statement in a recent article [3] which states:

"One virtue of synthetic detergents is that in general they give very soluble calcium and magnesium salts. It was expected that the detergency of synthetic detergents would not be adversely affected by hard water. However, the shift from soap to synthetic detergents did not entirely eliminate the hard water problem. Detergents provided only an apparent partial solution by not forming insoluble hard water salts. Later it was found that the addition of phosphate to synthetic detergents was necessary for acceptable detergency in hard water."

The phosphate is added as a water softener; the harder the water, the more phosphate required.

The relationship between the concentration of soap and syndets required to provide maximum soil removal has been determined by several independent investigators connected with firms that manufacture both soap and syndets, or who are employed as research consultants by such firms. The typical results found are shown graphically in Fig. 1 [2], from which it is evident that although the amount of syndets required to maintain the suds blanket level does not increase with an increase in hardness of the water, the amount of both soap and syndets required for maximum soil removal increases as the hardness of the water increases.

It is probable that the uniform appearance of suds when using syndets in different hardness waters has led to the apparent misconception that a given quantity of syndets is equally effective for soil removal in all waters regardless of hardness. In some cases it is possible that when enough syndets are added to obtain maximum soil removal the amount of suds produced may present a problem.

Another investigator [4] used zero hardness water and 400 mg/l hardness water while testing the efficiency

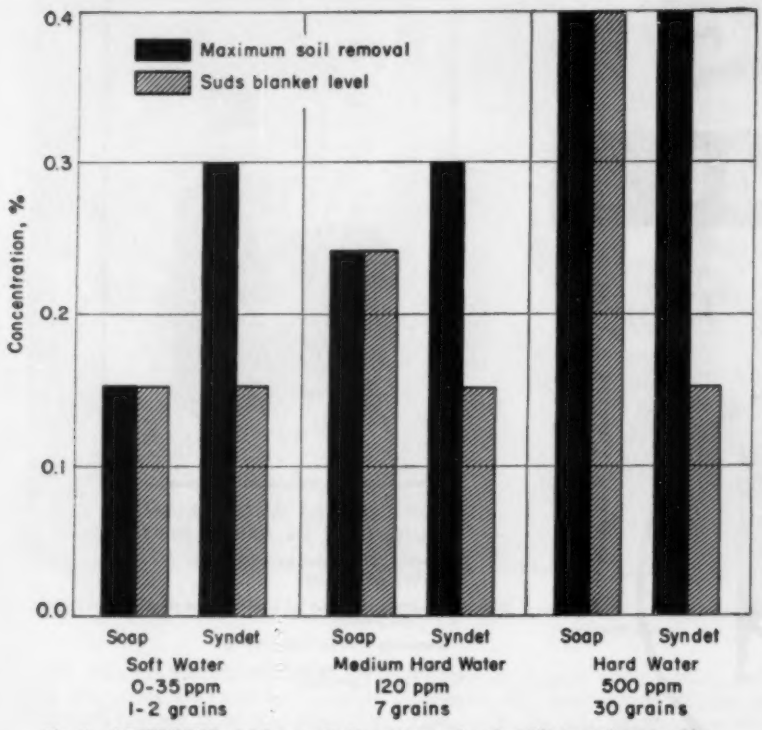


Fig. 1—DETERGENT requirements for suds vs cleaning (from reference 2).

of different makes of washing machines. Her report, which generally confirms the results shown in Fig. 1, states: "The concentration of high-sudsing built detergent in the wash water was 0.14 percent for soft water and 0.40 percent for hard water . . . These concentrations were selected after preliminary testing of several concentrations."

The preliminary testing was to determine the amount of syndets required for the different hardness waters to produce the same cleaning efficiency under controlled conditions. Under these conditions almost three times the amount of syndets were required for 400 mg/l hardness water than for zero hardness water.

Based on the relationship shown in Fig. 1, a comparison of the cost of soap and syndets when used with different hardness waters is summarized in Table 1 [(2)]. These data confirm the fact that the cost of soap for washing increases as the hardness of the water increases and also show clearly that the cost of syndets for washing likewise increases as the water hardness increases.

The application of these factors in evaluating the desirability of softening water is discussed later under the heading "Economic Aspects of Water Softening."

Development of various types of syndets for specific and general purpose continues. It is not known what the future may bring in the way of new and better syndets that will provide good cleaning properties for all materials and be less affected by the hardness of the water supply. With present technical knowledge, however, it appears that builders will continue to be required as additives to syndets to compensate for increased water hardness, and that the cost of cleaning when using hard water will continue to be greater than when using soft water.

More research is apparently necessary by the syndet manufacturing chemists to develop a product to which large numbers of people are not allergic, before syndets will replace soap for toilet use to any large extent.

TABLE 1

Cost per Washing with Soap vs. Synthetic Detergent[1]

Water Hardness							
Type	grains per gal.	Product	Conc. for Max. Soil Removal, %	Quan. per Box, oz	Retail Price per Box[2] $	Washings per Box[3]	Price per Washing[4], $
Soft	1 to 2	Soap	0.15 to 0.20	22	0.27	6 to 7	0.04 to 0.05
Medium		Syndet	0.25 to 0.30	18	0.27	3 to 4	0.08 to 0.10
Hard	7 to 10	Soap	0.25 to 0.30	22	0.27	4	0.06 to 0.07
		Syndet	0.30 to 0.35	18	0.27	2 to 3	0.10 to 0.11
Hard	20 to 30	Soap	0.40 to 0.50	22	0.27	2	0.10 to 0.13
		Syndet	0.40 to 0.50	18	0.27	2	0.13 to 0.16

[1]From "Soft Water, Detergents and Textiles," by Josephine Ringrose (2).
[2]Prices as of date of investigation (1951).
[3]Approx. number of washings per box, conventional machine.
[4]Approximate.

Methods of Water Softening

To soften water, the hardness-forming calcium and magnesium must be removed or replaced by non-hardness-forming chemicals. The former is accomplished by the lime-soda ash process and the latter by the cation exchange process, which is commonly called the zeolite process. It is also possible to soften by a combination of lime-cation exchange, which removes part of the calcium and magnesium and replaces part with non-hardness-forming sodium.

Because calcium and magnesium are the major hardness constituents in normal waters, only these two elements are included in this discussion. However, when these constituents are removed during a softening reaction the other minor hardness-forming elements (such as manganese, iron, strontium and aluminum) are generally removed, also.

Reactions that take place when lime is added to a hard water containing both calcium and magnesium are:

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow MgCO_3 + CaCO_3 + 2H_2O$$

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3$$

$$MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCl_2$$

$$Mg(NO_3)_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + Ca(NO_3)_2$$

$$MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaSO_4$$

Reactions involving the use of soda ash are:

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$$

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$$

$$Ca(NO_3)_2 + Na_2CO_3 \rightarrow CaCO_3 + 2\,NaNO_3$$

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SOFTENING by pebble lime is facilitated by the belt gravimetric feeders in the South County Plant of the St. Louis County Water Co.

The calcium carbonate ($CaCO_3$) and the magnesium hydroxide ($Mg(OH)_2$) are relatively insoluble and settle out of the water when the hydraulic velocities are reduced sufficiently, as when the water passes through a settling basin or clarifier. This precipitate must be removed periodically from the settling basin and disposed of to waste. Sometimes the volume of sludge produced presents a serious disposal problem.

The cation exchangers—zeolites or resinous type exchangers—are of complex chemical composition, so for simplicity are generally represented as Na_2Z or Na_2R, CaZ or CaR, MgZ or MgR, or H_2Z or H_2R, depending upon whether the exchanger is in the sodium, calcium, magnesium, or hydrogen form, respectively. Since most of the present cation exchangers are of the resinous type, the designation Na_2R and CaR is used in this discussion. In municipal softening the hydrogen exchangers are seldom used, although they may frequently be used in industrial water treatment.

The cation exchangers used in water softening resemble ordinary filter sand if they are one of the zeolites, or generally are of small bead shape if one of the resinous type exchangers. These compounds are remarkable in that they are capable of changing their composition by the exchange and re-exchange of their bases. In the regenerated, or sodium, form as Na_2R they are capable of removing the hardness-forming calcium and magnesium from water coming in contact or filtering through the exchanger. Upon exhaustion, this changes the composition of the exchanger to the calcium or magnesium form as CaR or MgR. The reaction is then reversible by the application of an excess amount of sodium chloride (NaCl), common table salt, to the exchanger.

The reactions that take place during the softening cycle are:

$$Ca(HCO_3)_2 + Na_2R \rightarrow 2NaHCO_3 + CaR$$
$$CaSO_4 + Na_2R \rightarrow Na_2SO_4 + CaR$$
$$CaCl_2 + Na_2R \rightarrow 2\,NaCl + CaR$$
$$Ca(NO_3)_2 + Na_2R \rightarrow 2NaNO_3 + CaR$$
$$Mg(HCO_3)_2 + Na_2R \rightarrow 2NaHCO_3 + MgR$$
$$MgCO_3 + Na_2R \rightarrow Na_2CO_3 + MgR$$
$$MgCl_2 + Na_2R \rightarrow 2NaCl + MgR$$
$$Mg(NO_3)_2 + Na_2R \rightarrow 2NaNO_3 + MgR$$
$$MgSO_4 + Na_2R \rightarrow Na_2SO_4 + MgR$$

The reactions that take place during the regeneration cycle are:

$$CaR + 3\,NaCl \rightarrow Na_2R + CaCl_2 + NaCl$$
$$MgR + 3NaCl \rightarrow Na_2R + MgCl_2 + NaCl$$

During the softening cycle there is no precipitate or no waste product formed. During the regeneration cycle the calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and excess sodium chloride(NaCl) must be discharged to waste, together with the water required to rinse out these brines from the cation exchanger.

The combination of lime and cation exchange softening would normally be used where the water contains both calcium bicarbonate hardness and magnesium and noncarbonate hardness and where, because of the relative cost of lime soda ash and salt, it is cheaper to remove the bicarbonate hardness with lime and the magnesium and noncarbonate hardness with cation exchangers using salt for regeneration. When other costs are equal, lime softening is preferable, for by this process the total salines in the water are actually reduced, whereas by the cation exchange process they may be slightly increased.

Municipal vs. Home Water Softening

Studies reported by T. E. Larson of the Illinois State Water Survey [6] [7] have established the relative cost of softening water in municipal treatment plants and by home-owned and home-serviced softeners. His study also shows the corresponding relative cost of soap to accomplish the same degree of softening. It is pointed out that municipal treatment seldom softens the water below a total hardness of 85 mg/l, while both the home-owned and home-serviced units soften the water to a nominal hardness of zero.

The relative costs as developed by Larson are shown in Table 2. Based on the smallest cost reported, which is for salt for softening 85 mg/l hardness water in home-owned units, the relative costs of the other methods or degrees of hardness are shown as a ratio to this smallest cost.

Examination of Table 2 shows that municipal softening is the cheapest, even when further softening to practically zero hardness is done by household-type softeners.

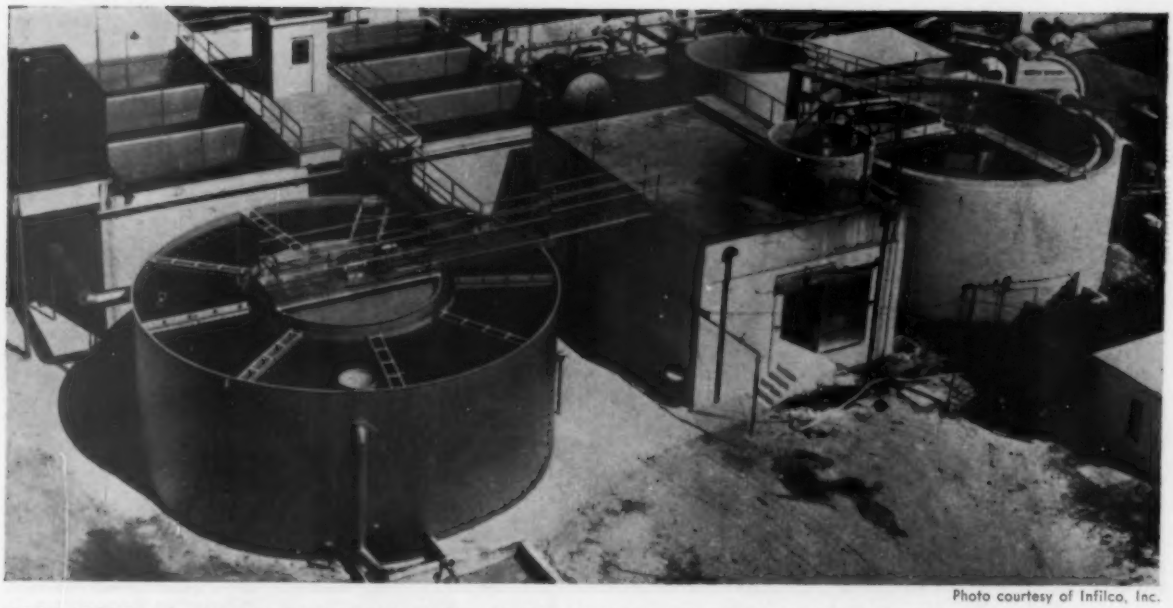


Photo courtesy of Infilco, Inc.

ACCELATOR® softening units at North Miami, Fla., include original concrete tank (right) with peripheral launder and later additional steel tank (left) with radial launders.

The results of a survey by one of the soft water service companies on the distribution of installations of rental type units are reported by Larson and are shown in Table 3.

The data show clearly that municipally softened water benefits those with low and medium incomes more than those with high incomes. However, the soft water service companies, as well as their customers, benefit from municipal softening. Not only is the major portion of the hardness removed in the municipal plant, but also any iron, manganese, turbidity, color and odors generally are removed.

Increasing Demand for Softened Water

Examination of the records shows that the demand by the public for softened water has been increasing at a high rate since World War II, regardless of the fact that the sales of synthetic detergents have been increasing rapidly during this same period. If actual experience in the home had shown that hard water was just as satisfactory as soft because of the availability of syndets, people would not be spending the money to provide themselves with softened water by buying their own household softeners or by subscribing to a soft water service.

Home-owned softener units were first installed about 1910. By 1956 there were an estimated 1½ million home-owned units in the United States and Canada.

It was about 1936 when the first soft water service unit was installed in a home. With this type of service the company owns all the equipment and regenerates and maintains it, the customer paying for the service by a monthly charge. By 1950 there were approximately one million such service units in use in the United States, and by the start of 1956 there were approximately 1½ million units in use. One large soft water service distributor alone had over 40,000 units of this type in Los Angeles County in 1956 and the business has been increasing at the rate of about 400 per month.

The demand for softened water is another of the results of the general improved standard of living of the American people. It is also the result of people's actually experiencing the greater desirability of this type of water for household use, plus the nationwide publicity by softener and soft water service distributors calling attention to the specific benefits received. It has been shown repeatedly that once a person has become accustomed to soft water, either completely softened by the household-type unit, or only partially softened in a municipal treatment plant, he will not be satisfied to go back to using a hard water supply [8].

TABLE 2
Comparative Costs[a] of Softening Methods

Softening Method	Initial Hardness, mg/l			
	85	250	340	510
Municipal (to 85 mg/)[1]		2.0	2.7	4.0
Home-owned (salt cost)[2]	1.0	3.0	4.0	5.7
Home-serviced	10.0	17.5	23.0	34.0
Soap	2.6	5.8	7.6	10.8

[1]Shown as ratio to lowest cost per given unit of water volume.
[2]Not including amortization of softener.

TABLE 3
Distribution of Rental-Type Softening Units

Income Bracket	Annual Buying,	Proportion of Spending Units,	Proportion of Total Rental-Type Units Installed,	Proportion of Families in Bracket Receiving Soft Water Service,
	$	%	%	%
High	> 7,000	6	27	90
Middle	2-7,000	64	57	18
Low	< 2,000	30	16	11

Photo courtesy of Permutit Co.

AUTOMATIC hardness tester on each zeolite softener at East Aurora, N. Y. makes standard soap tests at required intervals and automatically starts multi-port control valves for regenerative cycle when water tests hard.

Economic Aspects

Hard water is "hard" on the pocketbook. Special investigations were made by the Purdue University Experiment Station and the Michigan State Department of Health to determine what drawbacks there were, if any, to using hard water in the home which syndets cannot overcome [2]. Estimated national averages based on the results of these investigations indicate that:

1. A 25 percent saving is realized on fuel for heating soft water by eliminating deposits of scale which retard heat flow.

2. An 18 percent saving on repairing, cleaning and replacing plumbing that is caked with scale is realized.

3. Fabrics show 25 percent less wear and tear in soft water.

4. Soft water saves 16 percent wear and tear on utensils.

5. Food cooked in soft water retains its natural color and appearance, and its digestive qualities. In making tea and coffee it takes 50 percent less grounds in soft water than in hard water.

6. Soft water for skin care provides less possibility for skin dryness and irritation. Bathtubs do not develop the severe "bathtub ring" and expensive bubble bath preparations are unnecessary. Toilet bars, which are almost exclusively soaps, do not cause lime soap deposits on wash basins that must be removed by scouring powder and scrubbing. Shaving blades last 20 percent longer.

7. Washing machines do not develop suds lock or metal corrosion which syndets sometimes cause.

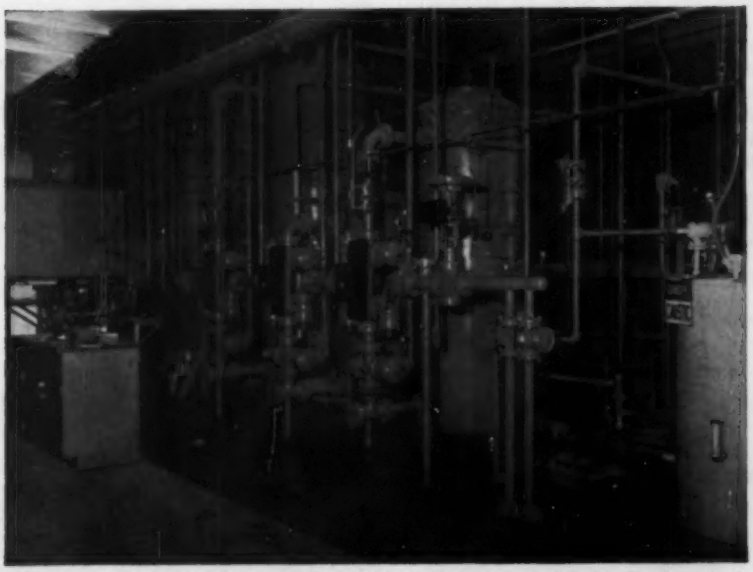
The foregoing percentages and favorable results will vary with the actual degree of hardness of "softness" of the water. The results reported in the foregoing listing are for water approaching zero hardness. This is the quality of water obtained from the individual household softener or from the rental-type home service units. Municipally softened water with a total hardness of 85 to 120 mg/l is still comparatively many times better than the 340 to 510 mg/l hardness natural water before treatment.

It is difficult, if not impossible, to attach a dollar value to many of the savings listed, but the saving is definitely there, and it is of appreciable magnitude. A dollar sign can still be placed on the saving of soap and/or detergents by the use of soft water in the home rather than hard water.

An average family of three will have at least three automatic washing machine loads of laundry a week, or a minimum of 156 a year. For purposes of comparison, let it be assumed that the natural water hardness is 20 to 30 grains per gallon (344 to 513 mg/l), which is softened in a municipal treatment plant to a total hardness of 5 to 7 gpg (85 to 120 mg/l).

Referring to Table 1, under these two conditions the approximate cost of soap per washing would be $0.06 to 0.07 for 5- to 7-gpg hardness water; for the same water syndet would cost $0.10 to $0.11. For 20- to 30-gpg water the corresponding costs would be $0.10 to $0.13 and $0.13 to $0.16, respectively. Thus, the increased cost per washing due to the use of the harder water would be $0.04 to $0.06 for soap and $0.03 to $0.05 for syndet, and the increased cost for 156 washings (full year) would be $5.24 to $9.36 for soap and $4.58 to $7.80 for syndet.

Thus, it is seen that the increased cost of soap and/or detergents when using 20- to 30-gpg hardness water rather than 5- to 7-gpg hardness water might range from $4.68 to



COMPLETE softening is accomplished by zeolite units at North Omaha plant of Omaha (Nebr.) Public Power District.

$9.36 per family per year *for laundry use only*. On the basis of the proportion of the different types of soap or detergent used, it is estimated that an amount equivalent to at least 50 percent of the foregoing costs would be attributable to toilet and kitchen use. Therefore, the increased cost for soap and/or detergents because of using the harder water would be at least $7.02 to $14.04 per family per year.

To this must be added the savings previously enumerated, to which it is difficult or impossible to place a dollar value. Considering the high cost of plumbing fixtures, hot water heaters, plumber's charges, and washable clothing, it appears quite probable that the savings should at least equal that shown for soap and/or detergents.

It could be expected, then, that a saving of at least $14.00 to $28.00 per family per year would accrue if 5- to 7-gpg hardness water were available for the family use rather than 20- to 30-gpg hardness water.

What would be the corresponding cost to this family of three if the water they use were softened in a municipal softening plant from a natural water hardness of 20 gpg (344 mg/l) to a hardness of 6 gpg (100 mg/l)? This cost is quite variable, depending on the type of hardness present (carbonate or non-carbonate), cost of chemicals, operating costs, and interest and amortization of the capital investment. All of these can vary greatly in different parts of the United States and depending on the type and size of the plant.

Costs Chargeable to Water Softening

The cost properly chargeable to softening would be materially different for (a) a surface water requiring coagulation and filtration in any event, with softening added as a refinement; and (b) a clear, iron-, manganese-, color-, and odor-free well water that normally would not be filtered except in conjunction with the softening process. In the former case, only the softening chemicals and small amount of additional plant operation and facilities required for softening should be charged to the cost of softening. In the latter case, all chemicals and all plant operation, including interest and amortization, should be charged to the cost of softening.

In the first case, the cost for softening would probably be less than $0.03 per 1,000 gallons. In the second case, the cost would probably range from about $0.06 to $0.10 per 1,000 gallons, depending on the type of treatment and the type and capacity of the softening plant. The cost of construction of a large treatment plant is less per million gallons of capacity than for the construction of a small-capacity plant. A cost of $0.06 to $0.07 per 1,000 gallons should be representative of all costs for softening in a plant of 30-mgd or greater capacity when reducing the total hardness of the water from about 340 mg/l to about 100 mg/l.

Photo courtesy Dorr-Oliver, Inc.

HYDRO-TREATOR® at Fiveash water plant serving Fort Lauderdale, Fla., is part of 8 mgd installation giving high-rate aeration, softening, filtration and chlorination.

An example of the actual annual cost of operation of a large softening and filtration plant will serve to substantiate these assumptions. The following costs are for the Metropolitan Water District of Southern California plant at La Verne, Calif.:

Design capacity: 200 mgd.
Type: Lime-zeolite softening and filtration.
Total cost of plant, exclusive of right-of-way: $7,662,980.
Method of financing: 50-year bonds at 4% interest.
1955-56 operations:
Total water softened: 55,681 mg, or an average of 152 mgd.
Average harness reduction: From a natural water hardness of 361 mg to a finished water of 141 mg, or a total reduction of 220 mg/l*.

Operating Costs:	Per Year	Per 1,000 gal.
Chemicals, power, and waste water	$ 794,284	1.426¢
Operation and maintenance	306,692	0.551
Employee retirement	14,632	0.026
Total operating cost	$1,115,608	2.003¢
Interest and amortization	356,712	0.641
Reserve for replacement	81,081	0.146
Total cost of softening	$1,553,401	2.790¢

* Normal softened water hardness is 125 mg/l. Higher annual average is result of operating plant in the summer as much as 67% above its designed capacity.

The salt for regeneration of the zeolite at this plant was purchased during this year of record at an unusually low price of $5.30 per ton delivered. If this cost of salt were doubled, which is about the normal price for such salt elsewhere, the foregoing unit costs would be increased $0.00878 per 1,000 gallons to a total unit cost of softening of $0.03668 per 1,000 gallons.

If the family of three, which has been discussed, uses an annual average of 140 gpd per capita, which is fairly representative of an average for the nation as a whole, they would use a total of 153,300 gallons per year. On the basis of the foregoing estimated costs of $0.03 to $0.07 per 1,000 gallons for softening in a municipal plant, the cost of softening the water used by this family would be from $4.60 to $10.73 per year.

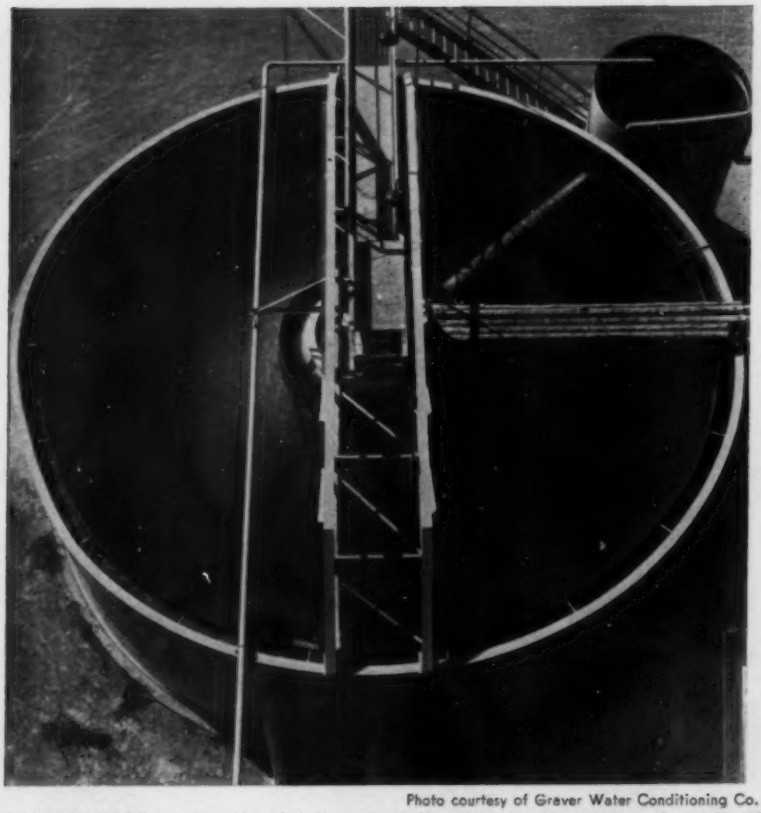


Photo courtesy of Graver Water Conditioning Co.

REACTIVATOR® construction details and clarity of treated water are shown in this bird's eye view of a municipal installation.

It is evident from this that under the conditions of water hardness that have been used in the examples, and which are fairly representative of average conditions throughout the hard water areas of the country, the cost to the individual family for municipally softened water is less than one-half the cost to this family if the water is not softened. In addition, the family has the pleasure of this more desirable water, which cannot be evaluated in dollars and cents. Regardless of the advent and increasing use of the synthetic detergents, the necessity for and economy of water softening still exists.

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Iron and Manganese Removal

By ESKEL NORDELL
Administrator of Laboratories, The Permutit Co., New York, N.Y.

IRON and manganese can be considered two of the most troublesome elements to be found in natural water supplies. As to the troubles caused by these elements, they are legion. To mention just a few: in the household—procelain fixtures, glassware, laundered materials, etc., develop unsightly stains which are very difficult to remove, and tea and coffee made with such waters become muddy-looking. unpalatable beverages. In the industries, even more serious difficulties are encountered—cotton, wool, and other textiles cannot be processed in such waters; rayon manufacture is impossible; dyeing is uneven and spotty; tanning is difficult; beverages develop troublesome and unsightly precipitates; quality pulp and paper production is impossible; etc.

In addition to these various difficulties, iron and manganese tend to favor the growth of iron and manganese micro-organisms popularly lumped together under the designation "crenothrix." These iron and manganese crenothrix growths clog pipe lines, meters, fixtures, nozzles, recirculating systems, and other water-handling equipment, cutting down flow rates and frequently breaking loose in large, clogging masses which, as they decompose, impart objectionable tastes and odors to the water.

The commonest form in which these metals occur is in the reduced state, as ferrous bicarbonate or manganous bicarbonate. These divalent bicarbonates are colorless compounds which exist only in solution and are most commonly found in deep well waters or spring waters. They can also, occur, in cases of iron or manganese pickup, when an unaerated water is pumped through distribution systems containing the insoluble, higher oxides or hydrated oxides. Under such conditions, a portion of these deposits may be reduced to the divalent form, which then goes into solution.

The second commonest form in which iron and manganese occur is in an organic or colloidal form, usually in surface waters and lower strata water in deep reservoirs, sometimes in shallow well waters and occasionally in deep well waters. Almost invariably, these waters have a rather high color, due to the organic matter present.

A third form is as the divalent sulfates—ferrous sulfate or manganous sulfate, but these are found only in acid waters such as (1) acid mine waters, (2) acid well or spring waters in the neighborhood of mines or contaminated by trade wastes, or (3) acid surface waters which similarly have been contaminated by acid mine waters or trade wastes.

A fourth form, of secondary origin and which applies almost entirely to iron, is as the suspended, insoluble higher oxide formed by corrosion of the distribution system or by aeration of a water containing ferrous bicarbonate, either of which causes the familiar "Red Water." In the absence of oxygen and presence of sulphides foul smelling "Black Water" issues from fire-haydrants or dead-end blow-offs.

Ferrous Bicarbonate—Manganous Bicarbonate

Iron or manganese, when present as the divalent carbonates, may be removed by one of four processes:

(1) Aeration, followed by settling, and filtration
(2) Oxidation with Chlorine, followed by settling and filtration
(3) Cation Exchange
(4) Manganese Zeolite

Aeration, Settling, and Filtration:

Both iron and manganese may be removed by aeration, settling and filtration but as manganese requires different conditions for its oxidation, the removal of ferrous bicarbonate will be considered first. *Ferrous* bicarbonate has a very appreciable solubility which varies somewhat according to the amount of free carbon dioxide present, while *ferric* hydroxide has a solubility which is so low that it is negligible. Therefore, on oxidizing ferrous bicarbonate to ferric hydroxide, the iron content of the water will be precipitated in a practically insoluble form. The oxidation is rapid and complete at pH values of 7.0 or over. At somewhat lower pH values, the oxidation proceeds at a much slower

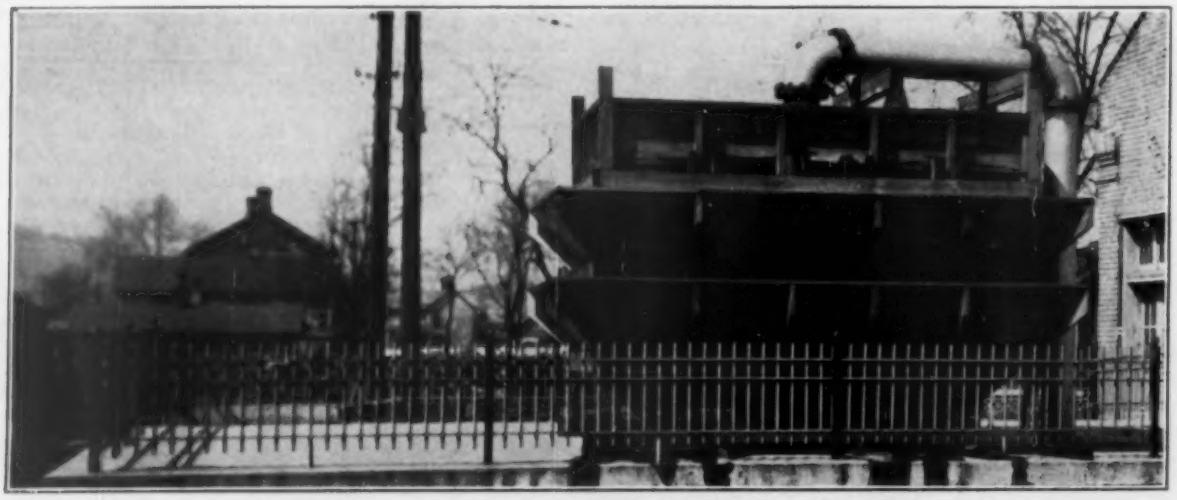

Fig. 1—COKE TRAY aerator preceding manganese zeolite filters and zeolite softeners, Coraopolis, Pa.

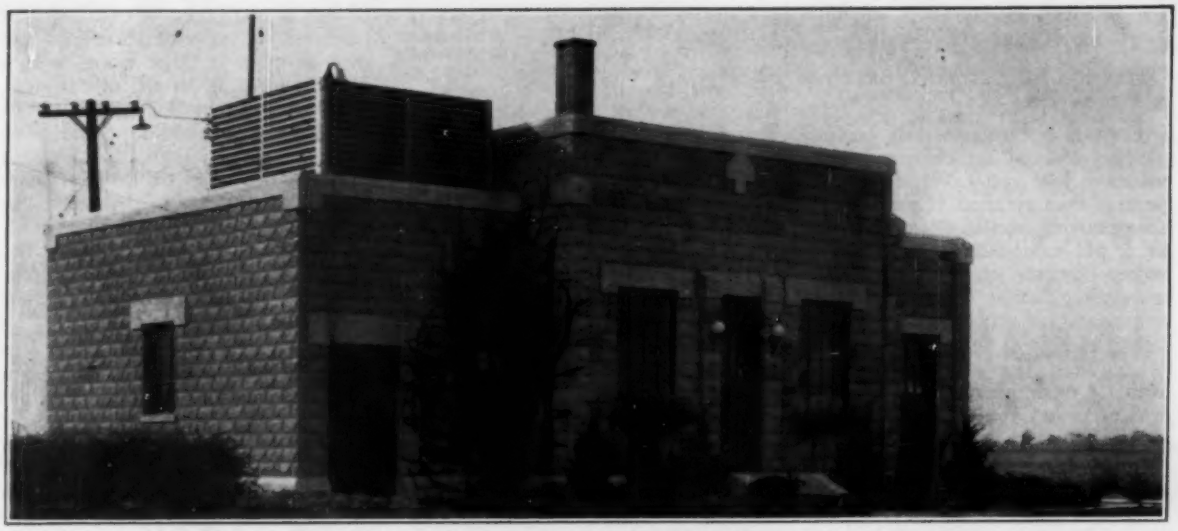

Fig. 2—WOOD SLAT TRAY aerator for iron removal on roof preceding filtration, and zeolite softeners, Genoa, Ohio.

rate, so if the pH value of the water is below 7.0, it is advisable to raise it in order to assure complete oxidation and removal of the iron. This effect of pH on the speed of the reaction is clearly shown in the following table of tests with detention periods up to 60 minutes following aeration:

As to the type of aerator employed, probably the most widely used type is the coke tray aerator. Wood slat tray aerators are also used and so are forced draft aerators. It is the usual practice to provide a catch basin or settling basin under or alongside the aerator with a nominal detention period of usually one-half hour or more. Occasionally, when waters have a favorable pH value, this detention period may be as little as 15 minutes. On the other hand, if the iron content is high, then it is advisable to remove the bulk of it by settling, in which case the basin should have a detention period of at least one hour.

From the catch basin or settling basin, the settled water is then passed through sand or Anthrafilt filters. The filters employed may be either of the pressure type or of the gravity type. The removal of iron by this process is very complete and the filter effluent will have an iron content of not more than 0.1 ppm.

If the iron content of the raw water is not above 1.0 ppm, settling before filtration is often dispensed with and, if the pH value is 7.0 or above, then pressure aeration, instead of open aeration, may be employed. In such cases, in order to avoid getting the water so saturated with air that it would spatter when drawn, only a portion of the water is by-passed through the pressure aerator tank and this flow is then mixed with the main flow of water. If the water, for instance, is under a pressure of 60 psig., then not over 20% need be passed through the pressure aerator tank.

Unlike ferrous bicarbonate, which requires a pH value of only 7.0 or slightly over for its oxidation, manganous bicarbonate requires a pH above 10.0 unless "ripened filters" are used. If ripened filters are employed, then a pH of 8.5 to 9.0 is sufficient.

The term "ripened filters" dates back to the rather early days of manganese removal when it was noticed that when a manganese removal plant of the aeration, settling and filtration type was first put in action, apparently little or no removal of manganese occurred for the first couple of days or so and then rather rapidly the plant began to function correctly and removed the managanese. This was due to a slight coating of the higher oxides of manganese on the granules of the filter bed which seems to serve as a catalyst in oxidizing and removing the manganese from the aerated water. One bad feature of the "ripened filters" is that in time, the coatings on the filter media tend to "shell off" and contaminate the effluent. To a great extent, this tendency can be overcome by occasionally dissolving and cleaning off the old coatings before they become too thick and then "ripening" the cleaned media before returning the filter to use.

Table II shows the effect of pH in oxidizing manganous bicarbonate when no catalyst (or "ripened" filter) was employed.

While Table II shows that a pH of 10.3 was required for complete oxidation of the manganese when no catalyst was employed, Table III shows that a pH of 8.5 was sufficient when a catalyst was present. In this case, the catalyst was stirred with the water which afforded an intimate contact similar to that of a ripened filter.

The coke tray type aerator is shown in Fig. 1 and wood slat tray type aerators are shown in Fig. 2. In the first two, iron is removed by aeration and filtration before softening by zeolite to the required degree. In the third, both iron and manganese

Table I

EFFECT OF pH ON THE OXIDATION OF FERROUS IRON BY DISSOLVED AIR

Raw Water		Iron in Aerated and Filtered Water (ppm)		
pH	Iron (ppm.)	(15 min.)	30 min.)	(60 min.)
5.0	10.0	9.0	—	7.5
5.5	10.0	5.5	4.6	4.0
5.95	10.0	5.0	4.0	3.5
6.15	10.0	4.4	3.5	2.5
6.5	10.0	2.8	1.8	0.3
6.65	10.0	0.7	0.2	0.1
6.8	10.0	0.2	0.1	<0.1
7.0	10.0	0.1	<0.1	<0.1
7.45	10.0	0.1	<0.1	<0.1
8.05	10.0	<0.1	<0.1	<0.1

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Table II

EFFECT OF pH ON THE OXIDATION OF MANGANOUS MANGANESE BY DISSOLVED AIR, WITHOUT STIRRING

Raw Water		Manganese in Aerated and Filtered Water (ppm)		
pH	Manganese (ppm.)	(15 min.)	(30 min.)	(60 min.)
8.5	10.0	—	—	10.0
9.0	10.0	—	—	9.0
9.3	10.0	8.5	8.0	7.5
9.5	10.0	7.5	5.0	3.2
9.7	10.0	3.0	1.3	0.9
9.95	10.0	0.9	0.7	0.6
10.3	10.0	<0.02	<0.02	<0.02

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are removed by aeration, chemical softening, settling and filtration.

Oxidation by Chlorine, Settling & Filtration:

Ferrous bircarbonate may be completely oxidized by chlorine at pH values as low as 5.0. While more expensive than aeration, it may be used for removing iron from waters as low as 5. pH value. Chlorine is of little value, however, in the oxidation of manganese, unless ripened filters are employed, for otherwise a pH practically as high as for oxidation by air is required. In some experiments which I made on this, a pH of 10.0 was necessary for complete oxidation and satisfactory settling.

Both metals may be oxidized by potassium permanganate, but since this chemical is rather expensive (over 25c per pound) it has only limited applications and then only for rather small concentrations of either metai. As with the aerating processes, final removal of the higher oxides is effected by (1) settling and filtration or (2) by filtration alone if the iron or manganese content of the raw water is low.

Table III

Catalytic Effect of 1 Gram per Liter of Previously Aerated and Precipitated Manganic Hydroxide, with Stirring, on the Oxidation of Manganous Manganese at Various pH Values

Raw Water + Catalyst		Manganese in Aerated and Filtered Water (ppm)		
pH	Manganese (ppm.)	(15 min.)	(30 min.)	(60 min.)
7.5	10.0	—	—	3.0
8.0	10.0	—	—	0.3
8.5	10.0	<0.1	<0.1	<0.1
9.0	10.0	<0.1	<0.1	<0.1

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Cation Exchange:

Iron or manganese in the form of the soluble, divalent bicarbonates, may be removed simultaneously with the hardness by the familiar Sodium Cation Exchange or Zeolite process. In this, the iron is taken up by the zeolite which gives up an equivalent amount of sodium in exchange for it. The zeolites which are used for this purpose are either of the greensand, carbonaceous or synthetic resin type. It is also the usual practice to limit the application of the cation exchange process to waters having not more than 1 ppm. of iron or manganese to each 2 gpg of hardness, up to a maximum of not over 10 ppm. In other words, with a water containing 10 gpg of hardness, 5 ppm of iron or manganese would be the specified maximum, while with waters having 20 or more gpg of hardness, 10 ppm of iron on manganese would be the specified maximum.

Regarding the completeness of removal of iron and/or manganese by this method, the effluent usually will not contain more than 0.1 ppm of iron or manganese. The capacity of the Zeolite for removal of these metals extends beyond the point at which zero hardness water is produced. In other words, the softener can be overrun a certain amount and still produce an iron manganese free water. This overrun or so-called "salt starvation" method has been used to a certain extent in softening municipal water supplies where the hardness was to be reduced to 5 gpg. In such cases, usually four softeners were employed and the softening runs were staggered at timed intervals so that while one was on the overrun, the other three would still be on the soft-

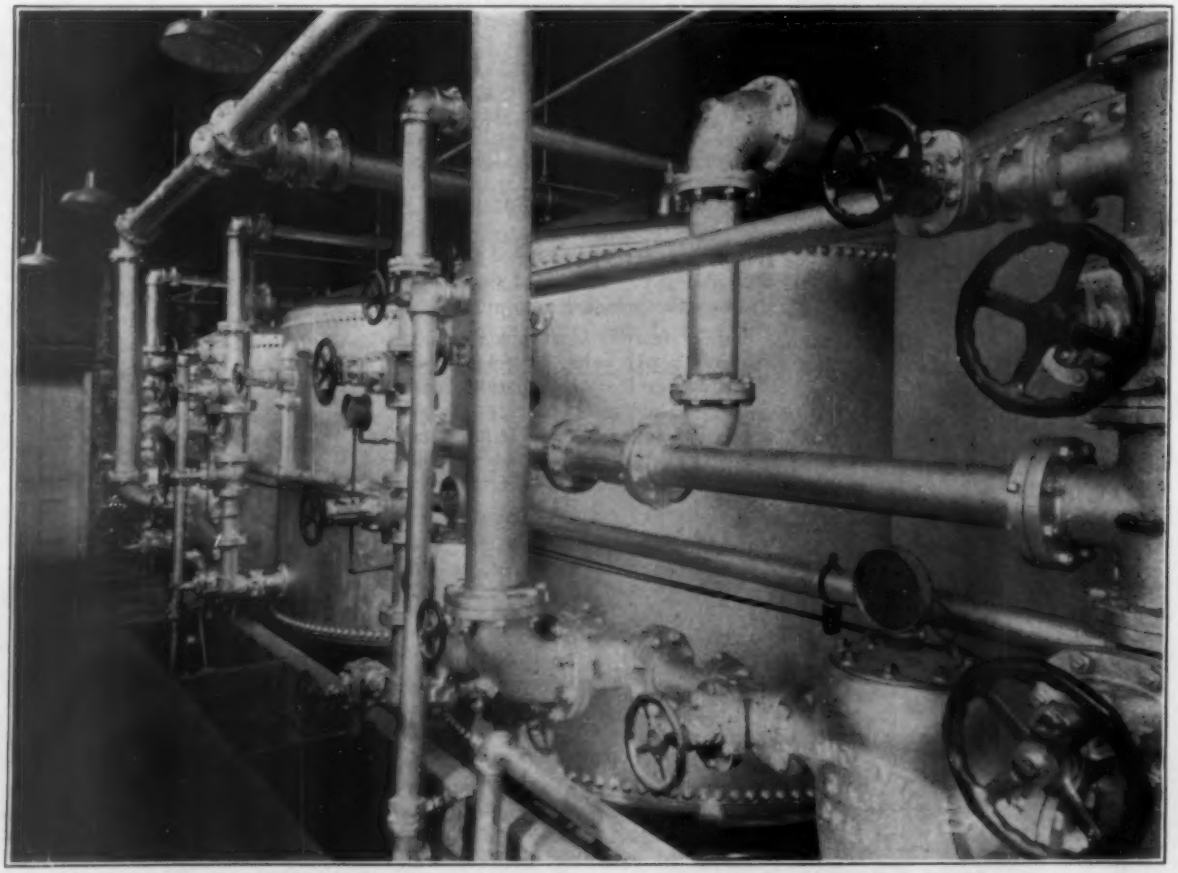

Fig. 3—ZEOLITE UNITS for combination iron and hardness removal at Wapakoneta, Ohio.

ening run. Fig. 3 illustrates a 4-unit iron removal and softening plant of this type.

This method of operation, however, does not result in a mixed effluent of unvarying hardness and it has been largely superceded by another method in which one portion of the water is softened to zero hardness and the iron or manganese simultaneously removed by cation exchange while another portion of the water is treated to remove these metals but not to soften the water. For instance, in one municipality which has a deep well water containing 1 ppm of iron and 20 gpg of hardness, three-fourths of the flow is passed through 5 zeolite water softener units which remove both the hardness and the iron. The other one-fourth is passed through 2 manganese Zeolite filters which remove the iron but not the hardness, after which the two flows join through a mixing valve to produce an iron-free (0.1 ppm or less) 5 gpg hardness water.

It is important in applying this zeolite process of iron removal to keep the entering raw water from contact with air. The reason for that is that if air comes in contact with the water before it passes through the zeolite bed, some of the iron would be precipitated and filtered out by the zeolite, and the zeolite softener is not designed to act as a filter. In other words, a filter would be operated at a rate of 2 to 3 gpm. per sq. foot and would be backwashed at rates of 10 gpm. per sq. foot or over. Zeolite softeners, on the other hand, are designed to operate at flow rates of from 5 to 8 gpm. per sq. foot and are backwashed at rates of from 5 to 6 gpm. per sq. foot.

Obviously, the iron and/or manganese may also be removed from all of the water, by aeration and filtration, before softening it to whatever degree is required. In Fig. 2, all of the water is aerated, settled and filtered before softening to the required degree with zeolite.

Cation exchangers, operating on the hydrogen (acid) cycle, will also remove iron or manganese, exchanging hydrogen for them. As these, however, are very rarely used in municipal water treatment plants, there is no need of detailing their operation.

MANGANESE ZEOLITE:

The Manganese Zeolite process is of rather limited application, but is of value in cases where the iron or manganese content is low and it is desirable to treat the water under pressure. For industrial and municipal use, it is the usual practice not to treat waters by this method unless the iron or manganese content is one ppm or less. For household use or for rather small industrial plants, this method may be used with waters containing up to 10 ppm of iron or manganese.

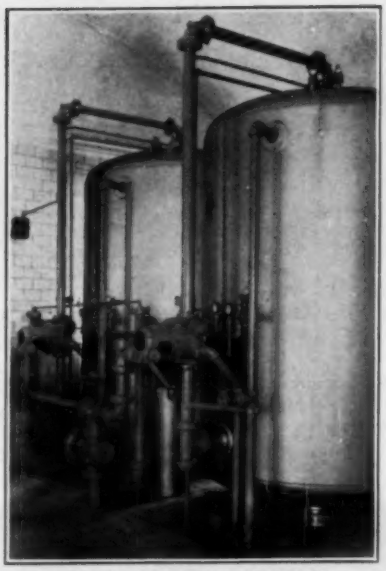

Fig. 4—MANGANESE ZEOLITE filters at East Lansing, Mich., remove iron from 25% of the water. Both iron and hardness are removed from 75%. The two portions are mixed.

Manganese zeolite is a granular material made from greensand zeolite by alternate treatments with manganous sulfate and potassium permanganate. Its capacity for removing iron or manganese is approximately 0.09 pounds per cubic foot and the amount of potassium permanganate required to regenerate it is 0.18 pounds per cubic foot.

In order to remove iron or manganese by this process, all that is necessary is to flow the water through the manganese zeolite filters at a rate of 3 gpm. per sq. foot. As the divalent iron or manganese comes in contact with the manganese zeolite it is oxidized to the insoluble hydrated oxide which is then removed by the filtering action of the granular bed. At intervals, it is necessary to backwash the filter to remove these deposits and the backwash rate used is 8 gpm. per square foot. Regeneration is required in order to restore the oxidizing power of the filter. Depending on the amount of iron or manganese present the flow rate and the number of hours used per day, regeneration may be some 5 to 20 days apart. The regenerant used, as previously mentioned, is potassium permanganate, and the reason why this process is usually limited in industrial or municipal use to waters containing not over 1 ppm. of iron is because potassium permanganate is a relatively expensive material to use as a regenerate. The cost, of course, for removing small amounts of iron is not high, but with larger contents of iron, the cost would be excessive as compared with other methods. A two-unit plant of this type is shown in Fig. 4.

Organic or Colloidal Iron and Manganese

In highly colored surface waters, iron or manganese is frequently present in an organic or colloidal form which cannot be completely removed by any of the foregoing processes. Some highly colored shallow well waters and more rarely a highly colored deep well water will also contain iron or manganese in this form.

In making water analyses, the iron content particularly is often expressed as "Total Iron" and then possibly a portion of this is expressed as "Soluble Iron." If the water contained only ferrous bicarbonate, then the latter figure would be rather meaningless for it would depend on whether the sample had been analyzed immediately, as drawn, or whether it had been partially or completely oxidized and precipitated during the interval between sampling and making the analysis. However, the reason for making this "Soluble Iron" determination on shipped samples is simply so that, if any soluble iron is present, then further tests can be made to see if this soluble iron is merely some which escaped oxidation or if it is due to colloidal or organic iron.

For instance, one clear but highly colored water sample with a color of 450 ppm. had a total iron content of 12 ppm all of which was in solution when the sample arrived in the laboratory some 5 days after the sample had been drawn. Aeration and filtration had absolutely no effect on the iron content even when a detention period of 48 hours was used between aeration and filtration.

Another water, with a color of 35 ppm and an iron content of 3.5 ppm was aerated, the pH was adjusted to 8.3, a detention period of one hour was allowed after which the water was filtered. This treatment only reduced the iron content to 2.6 ppm.

In another experiment in which a highly colored swamp water had 2.0 ppm. each of manganous bicarbonate and ferrous bicarbonate, both expressed as the metals, aeration plus increasing the pH to 10.5 plus one hour detention period plus filtration resulted in removing only a little less than one-half of both the iron and manganese content.

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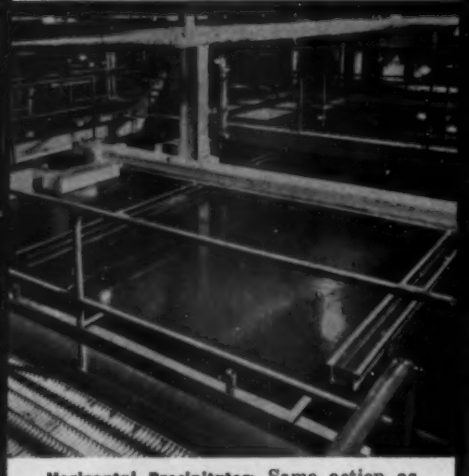

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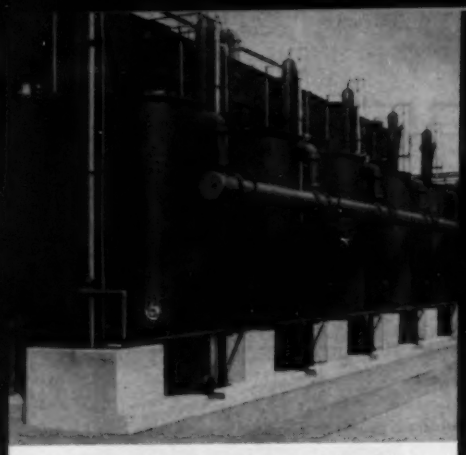

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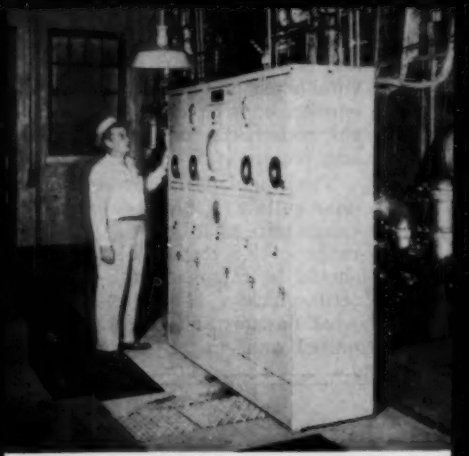

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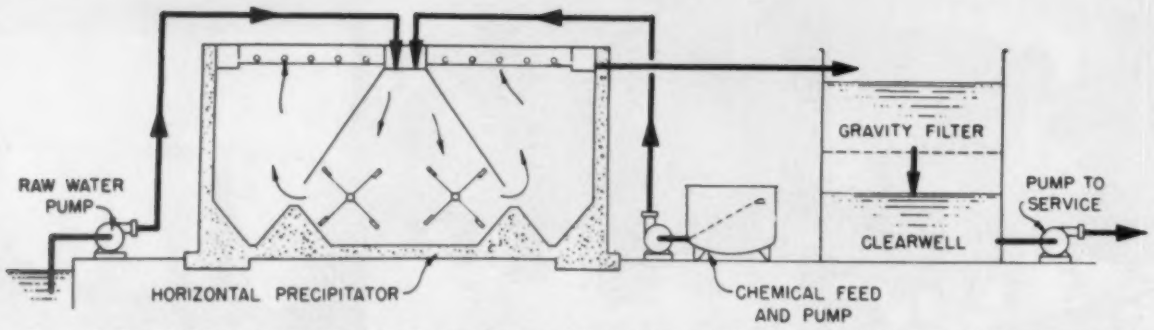


Fig. 5—FLOW DIAGRAM of Spaulding-Permutit Precipitator and filter for removal of organic or colloidal iron and/or manganese by flocculation, clarification and filtration.

Such waters, however, usually respond to coagulation, settling and filtration which removes the iron or manganese as well as the great bulk of the color. It is advisable to run jar tests in the field, on freshly drawn samples, to find what dosage of coagulant is required, what is the most favorable pH range for coagulation and whether or not the use of a coagulant aid, such as clay or activated silica, is also required.

The coagulant usually used is aluminum sulfate as this works well at pH values somewhat below 7.0, say in the range of 5.5 to 6.8. Floc formation should be rapid and the floc should settle quickly. These tests will show what dosages and conditions are required and, under favorable conditions, the content of iron or manganese should be reduced to not more than 0.1 ppm.

The equipment used consists of chemical feeds, reaction chamber and settling equipment or precipitator and floc-former of settling basin type and filters. A flow diagram of this is shown in Fig. 5.

Ferrous Sulfate—Manganous Sulfate

In certain sections, especially in mining districts, acid waters are found —both surface and ground waters. Such waters may contain both ferrous and manganous sulfates as well as free sulfuric acid. Some of these ground waters are so heavily charged with acid and sulfates that they are not worth treating but other ground waters are amenable to treatment. As for the surface waters, the acid content has been so greatly diluted that neutralization usually offers no serious difficulties.

The usual method of treating these acid waters is to neutralize them with either soda ash or lime, aerate or chlorinate if required, settle and filter. There is usually little difficulty in oxidizing and precipitating the iron but the manganese removal may be much more difficult. Raising the pH value or using ripened filters is of value and in a few cases with surface waters where the manganese content is small, permanganate or sodium chlorite (chlorine dioxide) have been advocated to oxidize the manganese.

WEIGHTS OF MATERIALS

Pounds per Cubic Foot — Average

BRICK	
Common Red	100
Silica	105
CEMENT	
Portland	94
Hydraulic	60
COAL AND COKE	
Anthracite	53 to 57
Bituminous	49
Charcoal	18
Coke	26
CONCRETE	
Cement, fine	137
Rubble, coarse	119
EARTH	
Loam, dry, loose	76
Loam, packed	95
Loam, soft, loose mud	108
Loam, dense mud	125
LIME	
Quick, loose lumps	53
Quick, fine	73
LIME STONE	
Large blocks	168
Irregular lumps	96
MASONRY	
Granite or limestone	165
Mortar, rubble	154
Dry	138
Sandstone, dressed	144
METALS	
Aluminum	166
Brass, cast	524
Bronze	534
Copper, cast	537
Copper, rolled or wire	555
Iron, cast	450
Iron, wrought	482
Lead, cast	708
Lead, rolled	712
Steel, cast	490
Steel, rolled	495
Tin, cast	459
Zinc, cast	438
OILS	
Engine	55
Crude	48
Petroleum	55
Gasoline	43
SAND	
Dry and loose	100
Dry and packed	110
Wet and packed	130
Gravel, packed	118
Gravel, bank	111
Gravel, dry	74
WATER	
Water, as ice	59
Water, at 32° F.	62
Water, at 212° F.	60

Color Coding

In water and sewage works.

by H. E. LORDLEY

Assistant Director, Department of Public Utilities, City of Richmond, Va.

COLOR is an old word re-emphasized in today's world of color television, two-toned automobiles, and eye-soothing paints for the home and industrial plant. The superintendent of the smallest pumping station or the largest filtration plant can establish a color code for the identification of equipment and piping, both to facilitate repairs and to improve the general appearance of the plant.

Color combinations have been used since Biblical days for identification of armies by the color of their attire. As early as 1908, Bryan[1] presented a paper on the "Identification of Power House Piping Colors"; this was followed by various articles on the subject until 1920-21. In the early 1920's a number of associations published papers on methods of identification and the American Standards Association organized a committee on the subject in June 1922.

During World War II, industrial plant managers realized the importance of proper identification of piping systems when many inexperienced employees were hired, which resulted in unusual cross connections and costly shut-downs. The ASA Code was used in many of these plants, but the waterworks industry has been slow in adopting color coding. It is recommended that operators read the latest revision of the publication known as American Standards Association A13.1—1956, "Scheme for the Identification of Piping Systems,"

*At the request of the Editors, Mr. Lordley prepared this article as a modernized and updated version of an article which he wrote on this subject several years ago. Although this article was prepared with specific reference to a water plant, the basic ideas, concepts and information are just as applicable to sewage works where color coding is also highly desirable.

TABLE I

ASA System of Color Identification for Piping

Classification	Predominant Color	Legend Letter Color
F—Fire protection equipment	Red	White
D—Dangerous materials	Yellow (or orange)	Black
S—Safe materials	Green*	Black
P—Protective materials	Bright blue	White

*Or the achromatic colors white, black, gray or aluminum.

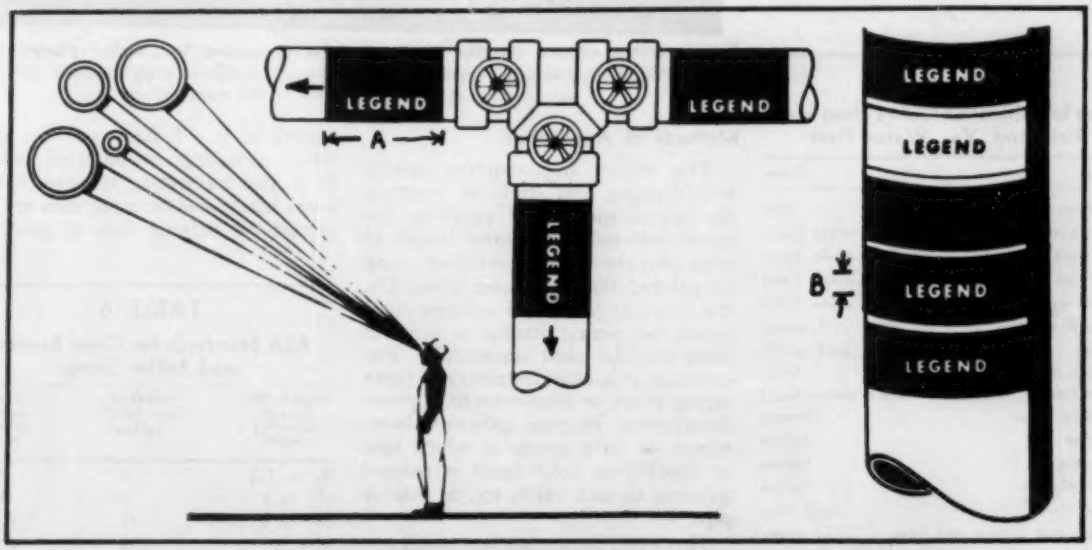


Fig. 1—LEGEND placement, width of color bands, and size of letters for various diameter pipes

From ASA "Scheme for the Identification of Piping Systems," by permission

TABLE 2

Classification Assignment of Materials

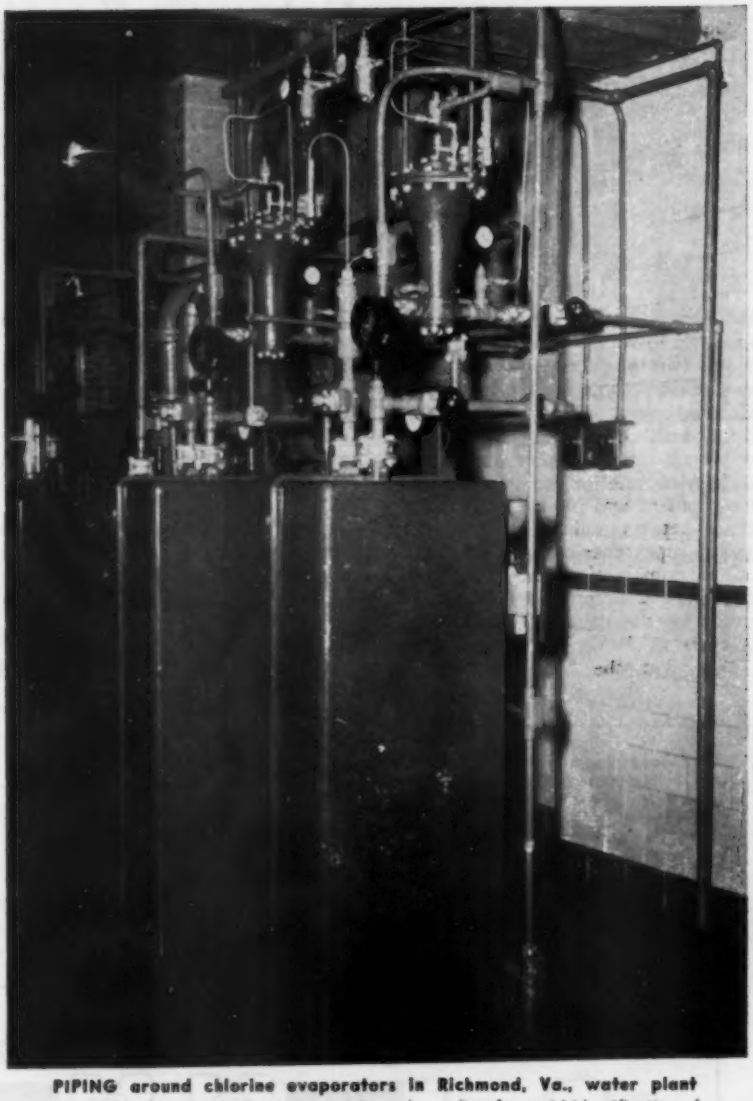
Material Piped	Classification
Alum solution	S
Carbon dioxide	D
Chlorine	D
Ammonia	D
Soda ash solution	S
Water	S
Steam	D
Water, fire protection	F

dated January 1956 and published by the American Society of Mechanical Engineers, 29 West 39th Street, New York, 18, N. Y.; price $1.00.

The first step in any system is to establish a definite color code according to the character of the various materials in the piping system. The ASA system is shown in Table 1. In this system all materials are listed and each assigned to one of the classes, as illustrated by Table 2.

Table 3 illustrates the system used in the Richmond, Va., plant identification of pipes common to water, plants. However, this system was established in 1940 and is not in conformity with the ASA recommendations previously listed.

The system has the advantage of a large number of colors and results in a variety of hues in an otherwise monotonus piping system. Many favorable comments on this color arrangement have been received from visitors particularly from classes of school children.



PIPING around chlorine evaporators in Richmond, Va., water plant
Illustration shows type of system requiring color coding for rapid identification of control valves as well as eye appeal for the many visitors

TABLE 3

Piping Identification Colors Used in the Richmond, Va., Water Plant

Piping	Color
Fire lines	Red
Sump pump lines	Red, white band
Raw water pumps	Red, white band
Drains on chemical machines	Red, white band
Waste water pump	Red, white band
Finished water	Dark green
Motors	Dark green
Electric conduit	Gray
Steam lines	Black, yellow band
Chemical lines	Orange
Chlorine	Yellow
Ammonia	Yellow
Sulfur dioxide	Yellow
Sewers	Light blue
Wash water pumps and lines	Light green
Air ducts	Aluminum
Hot water	Aluminum
Venturi meter lines and stacks	Brown

Methods of Application

The second step requires careful consideration and study in selecting the actual method of applying the colors selected. The entire length of pipe, plus the valves and fittings, may be painted the designated color. Or, the alternate method of painting color bands on piping having a uniform color may be used successfully. For example, it is often necessary to paint piping white or aluminum to improve illumination in pipe galleries, basements, or dark areas, in which case an identifying color band is painted adjacent to each valve, tee, or branch pipe.

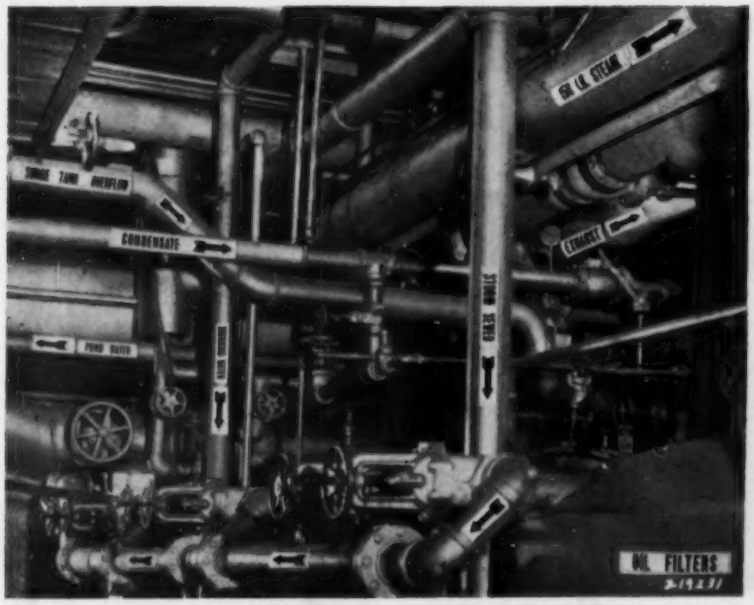
However, the author has found one disadvantage in painting entire lengths. It is a fact that painters become tired of using one color, which results in less footage per day than when switching to different colors. It is also interesting to note that in cases where one or more men are assigned the definite duty of painting,

TABLE 4

ASA Standards for Color Banding and Letter Sizing

Outside Dia. Pipe or Covering inches	Width of Color Band*, inches	Size of Legend Letters**, inches
3/4 to 1 1/4	8	1/2
1 1/2 to 2	8	3/4
2 1/2 to 6	12	1 1/4
8 to 10	24	2 1/2
Over 10	32	3 1/2

*Dimension A in Fig. 1.
**Dimension B in Fig. 1.



IDENTIFICATION of piping and flow direction
Easily accomplished with "stick-on" markers.

their personal interest and pride in the work increases in keeping each line painted the proper color. New employees assigned to painting learn the piping system quickly and can be transferred later to the mechanical maintenance division or the operating division with a thorough knowledge of the plant.

If a color band system is selected, this can be used in conjunction with stenciled words, letters and figures or more stripes of color at the edges of the band to indicate the exact identification of the system. Decals or plastic bands may be applied and are manufactured by a number of companies. W. H. Brady Co., 16 E. Spring St., Chippewa Falls, Wis., can furnish pipe markers for all materials and liquids normally found in a water plant. For example, labels can be ordered to identify raw water, treated water, waste water, hot water, cold water, well water, etc. An accompanying illustration shows how these "stick-on" labels can be used effectively.

Figure 1 shows the ASA system[2] for placement of legends on pipes. Table 4 gives width of color bands, and size of letters for various diameter pipes.

Color and Paint Selection

In selecting colors it always should be remembered that the reflective value of paints varies with the shade. Gray, which from a physiological or visual standpoint is situated about halfway between white and black, reflects approximately 25 percent of the incident standard white light, and is near the permissible limit of reflective value for poor illumination. In pipe galleries, aluminum or white paints give maximum illumination and increase the efficiency of maintenance operations.

The type and quality of paint used in a plant is often dependent on the judgment of the superintendent. Usually, he is required by the purchasing department to submit specifications on every item. Several government publications[3,4] are available to aid in the difficult job of selecting paint.

Labor turnover is increasing in water and sewage plants, making color coding essential for the safety of the employees. Civil Defense training also must be considered, and the possibility of outside assistance from other plants in the vicinity, in which case the identification of piping systems and equipment would aid in operating the plant.

References

1. Bryan, William H., "Identification of Power House Piping by Colors," ASME Proceedings, *30*: 773 (1908)
2. "American Standard Scheme for Identification of Piping Systems"—ASA A13.1-1956.
3. "Paint Manual." Report BMS, Catalog No. C 13.29: 105, available from Superintendent of Documents, Washington 25, D.C.; price $1.50 (Oct. 11, 1945).
4. "Index of Federal Specifications." Available from Superintendent of Documents, Washington 25, D.C.; price $1.75.

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Fundamentals of Applied Fluoridation

by JAMES L. HENRY and JAMES F. HASKETT
Technical Service Engrs., Water & Waste Division Fischer & Porter Co., Hatboro, Penna.

FLUORIDATION is the practice of purposely adding to a potable water supply a specified quantity of some particular industrially prepared inorganic chemical compound containing the element fluorine, present in the compound in its reduced state as the fluoride ion.

It is not the intent to discuss the pros and cons of the addition, because there is an abundance of literature available that deals with these aspects of the practice of fluoridation. It is however, the intent to discuss applied fluoridation as related to the following:

(1) The chemical compound used in the practice of fluoridation.

(2) A graphical method that can be applied to determine the quantity and cost of each chemical compound required to impart to the water the concentration of fluoride recommended as being optimum.

(3) The mechanics involved in applying the calculated quantity of chemical compound.

(4) The type of equipment that is required to provide the mechanics for applying the calculated quantity of chemical compound.

(5) The factors involved in the selection of the particular compound that would present the most economical approach to applied fluoridation.

Fluoridation Agents

The individual chemical compounds used in the practice of fluoridation may be referred to as fluoridation agents. The agents most commonly used are hydroflusilicic acid, hydrofluoric acid, sodium fluoride, sodium silicofluoride, and ammonium silicofluoride. For purposes of discussion as related to the actual application of these compounds this list may be subdivided into two distinct groups. This subdivision, based on the physical state in which the compounds are commercially available, is as follows:

Group A: compounds commercially available in solution form:
(a) Hydrofluosilicic acid.
(b) Hydrofluoric acid.

Group B: compounds commercially available in Solid Form:
(a) Sodium fluoride.
(b) Sodium silicofluoride.
(c) Ammonium silicofluoride.

Solution form compounds are those commercially available in the form of an aqueous solution. Solid form compounds are those commercially available in the form of a dry crystalline material possessing some varying degree of fineness. The degree of fineness may range from that of a granular material to that of a powder. Table 1 lists the name, chemical formula, and other pertinent information for each of the compounds cited.

Of the agents listed, there are certain objections raised to the use of either hydrofluoric acid or ammonium silicofluoride.

The objection to the use of hydrofluoric acid is related to the hazards involved in handling this potentially dangerous chemical. Handling aqueous hydrofluoric acid requires the observance of every precaution to prevent injury and avoid accident. Therefore, its use requires the practice of extreme caution at all times and the use of proper personal protective equipment during the actual handling operation. It should be pointed out that the handling of aqueous hydrofluoric acid need not be hazardous provided its nature is understood and its dangers recognized.

The objection to the use of ammonium silicofluoride is of an entirely different nature. This objection is related to its use when the treatment practice requires the use of chlorine for the purpose of disinfection. Because the ammonium ion of the ammonium silicofluoride will react with chlorine to form chloramines, the use of ammonium silicofluoride in conjunction with chlorine may require some change in operating practice. Actually this does not adversely affect the chlorination practice, but it may affect the interpretation of the chlorine residual as related to the quantity of residual chlorine required for effective disinfection.

Related to the hazards involved in the handling of chemicals in general, it should be pointed out that any operation of handling either solution form or solid form compounds involves certain hazards. The only difference is the specific nature of the hazard involved. In handling solid form compounds the hazard is dust; in handling solution form compounds the hazard is splashing. The degree of hazard is related to the amount of dust or the concentration of the solution, and both of these are in turn related to the toxicity and/or adverse effect upon contact with the body of the chemical compound in question. In general, it should be further pointed out that all chemical compounds are toxic to some degree.

Fluoridation Agent Requirements

The first problem that confronts the individual contemplating applied fluoridation is that of determining the quantity of fluoridation agent that must be added to the water to attain the total recommended concentration of fluoride. This is generally 1.0 to 1.2 ppm. The quantity of any selected agent that will be required is dependent on the following factors:

(1) The quantity of water to be treated.

(2) The existing concentration of fluoride in the water to be treated.

(3) The available fluoride content of the commercial form of the fluoridation agent.

The first two factors are the essential operating data that must be known or ascertained for each individual installation. Calculations using this data and the available fluoride content of the commercial form of

the agent must be made to establish the requirements for any particular installation. The available fluoride content of the fluoridation agent is dependent on both the percent composition (purity) of the commercial form of the agent and the relative weights of the various constituents that comprise the pure form of the agent. Therefore, the most direct stepwise solution to the problem of determining the quantity of fluoridation agent, which is applicable to any particular treatment installation, is as follows:

(1) Determine the weight of fluoride required for the treatment.

(2) Determine the weight of the pure form of the agent needed to supply the fluoride required for the treatment.

(3) Determine the weight of the commercial form of the agent needed to supply the fluoride required for the treatment.

Although the third step in the solution to the problem may seem superfluous, it is essential because it takes into account the percent composition of the commercial form of the fluoridation agent. It is important to point out that the exact composition of the fluoridation agent will be dependent on (a) the commercial grade that is purchased and (b) the variations in the quality of each shipment. Because this information is essential to the correct solution of the problem, the determination of the exact quantity of fluoridation agent can be made only after this information is available. This should be obtained from the local commercial suppliers.

Because these calculations become laborious when conducting a survey of the requirements of each of the available agents, Figures 1 and 2 and Table 2 are presented to simplify the calculations and reduce to a minimum the time required to establish the requirements for any particular installation.

Figure 1 is used to establish the pounds of available fluoride that must be added to one million gallons of water to supply the additional fluoride required for the treatment. Figure 2 is used to establish the pounds of pure form chemical compound that must be added to one million gallons of water to supply the available fluoride required. The composition factors in Table 2 correct for purity and are used to calculate the pounds of the commercial form of the agent that are required to supply the available fluoride.

To calculate the required weight of the commercial agent, multiply the required weight of the pure agent from Figure 2 by the factor in Table 2 that corresponds to the percent composition of the commercial agent.

TABLE I

Fluoridation Agents

(Commercial Form)

Name	Chemical Formula	Approx. Composition* %	Approx. Cost, $/lb*	Avail. F^-, lb/100 lb	Approx. Cost of Avail. F^-, $/lb
Solution form compounds:					
Hydrofluosilicic acid	H_2SiF_6	30	0.06	23.8	0.25
Hydrofluoric acid	HF	60	0.19	57.0	0.33
Solid form compounds:					
Sodium fluoride	NaF	95	0.14	42.9	0.33
Sodium silicofluoride	Na_2SiF_6	99	0.09	60.0	0.15
Ammonium silicofluoride	$(NH_4)_2SiF_6$	99	0.11	63.4	0.17

*Contact local supplier for exact values; transportation charges and container deposits not included.

Cost

Of particular interest to any community or individual contemplating applied fluoridation is the cost of the fluoridation agent required for the treatment. The actual cost of any particular agent will be dependent on:

1. The commercial grade purchased.
2. The quantity purchased.
3. The transportation cost.

To calculate the cost, multiply the number of pounds of the commercial agent required by the delivered cost per pound.

Application

The application of the fluoridation agents will require at least one and possibly two distinct operations. These operations are (a) the preliminary preparation of the fluoridation agent, and (b) feeding the prepared fluoridation agent. The form in which the agent is received from the supplier governs whether one or both of these steps will be required.

Solution form compounds are received in a physical state that is suitable for direct application; therefore, no preliminary preparation of these compounds is required (in certain cases dilution may be desired). Solid form compounds, on the other hand, must first be converted to solution form for application.

Therefore, all solid form compounds require preliminary preparation. This involves dissolving the agent in water and, ideally, requires the preparation of an aqueous solution of definite and known concentration. This operation is essential, as the quantity of the agent involved is relatively small and the specifications of the treatment are so rigid that it would be unsound practice to apply solid form compounds in the dry state.

The preliminary preparation of the solid form compounds can be accomplished with either of two basic types of equipment which are available: (a) dry feeders and mixing tanks, and (b) saturators.

The dry feeder type is designed to accurately measure a definite quantity of solid form material per unit of time. The dry material is discharged from the feeder to a solution preparation mixing tank.

The discharge from this tank should be constant and should be regulated by a float valve or other device so that the solution discharged from the tank is maintained at a definite concentration.

The feeder can be interconnected with other equipment for automatic proportioning. Dry feeders are of two general types: (a) volumetric and (b) gravimetric. The former type delivers a definite volume of dry material per unit of time; the latter delivers a definite weight of the dry material per unit of time.

A saturator is a tank into which a quantity of solid form material is placed to make a bed through which water is drawn at a low enough flow rate so that it becomes saturated with the material in the tank. The material is added by hand, intermittently, to maintain a sufficient quantity of solid form material in the tank.

The water supply to the saturator

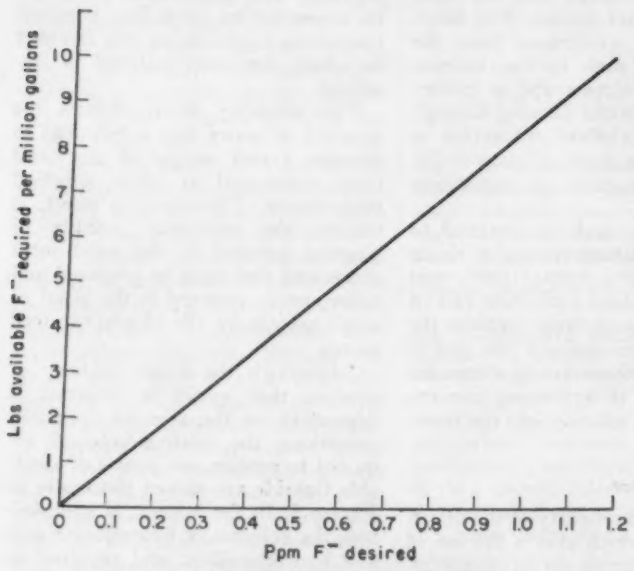


Fig. 1—AVAILABLE fluoride ion requirements.

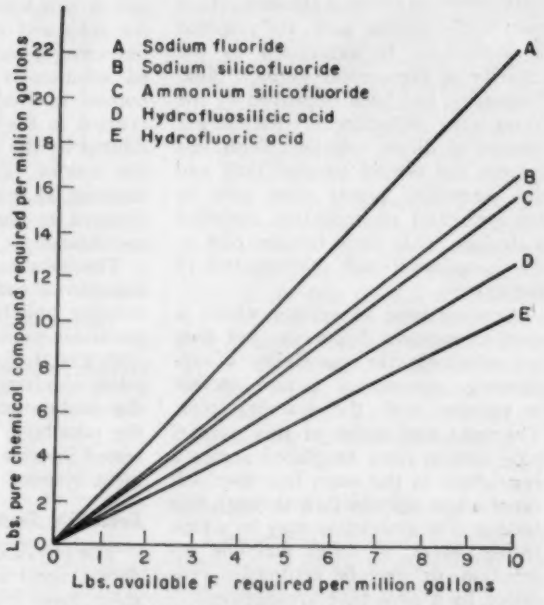

A Sodium fluoride
B Sodium silicofluoride
C Ammonium silicofluoride
D Hydrofluosilicic acid
E Hydrofluoric acid
Lbs. pure chemical compound required per million gallons
0 2 4 6 8 10 12 14 16 18 20 22
0 1 2 3 4 5 6 7 8 9 10
Lbs. available F required per million gallons

Fig. 2—PURE FLUORIDE compound requirements.

is generally added automatically and is either maintained constant by a float valve or is added on a controlled intermittent basis. To enhance the saturation there should be some form of agitation in the tank. Also, to prevent undissolved material from being carried over into the system, the saturated solution is withdrawn after first passing through a suitable medium such as filter sand. The saturated solution is withdrawn at a controlled and regulated rate by a suitable pump.

The second operation, feeding the prepared fluoridation agent, involves delivering a controlled and regulated volume of the aqueous solution (of definite and known concentration) to the point of application. This operation is common to either solid form or solution form compounds.

Because the quantities of solution involved are relatively small, a chemical feed type pump is generally used to perform this operation. This type is specifically designed to accurately meter and deliver small volumes of liquid. For this application, the pump must be constructed of materials suitable for handling these solutions, which are of a corrosive nature.

The method to be used for delivering a regulated volume of solution prepared from solid form compounds is dependent on both the equipment used to prepare the solution and the pressure that exists at the point of application.

For open channel feeding, using a dry feeder, the continually regulated volume of prepared solution can be fed without the use of a pump if the point of application is lower than the solution preparation tank so that it may be fed by gravity. This is possible if the design of the unit is such that the through-put rate is governed and regulated by the input to the unit. However, for closed pipeline feeding the prepared solution must be pumped into the line. Under these conditions it is essential to use a suitable pump that maintains a relatively constant rate of withdrawal.

When using a saturator, a metering pump must always be used, irrespective of the condition that exists at the point of application, to maintain a constant withdrawal rate.

Solution form compounds are much easier in handling and in adding to the water supply at controlled rates. Because these compounds are purchased at exact and concentrated strengths, their application involves only accurate metering, which can be done readily by a small metering pump directly from the container in which they are purchased.

Pertinent Application Problems

There are two pertinent problems that must be overcome in the application of the fluoride solution.

The first problem is related to the method of uniformly applying and adequately dispersing a small volume of solution at the point of treatment. The most accurate means available for metering this volume of solution is a chemical feed pump. This type of pump is extremely accurate for metering a small volume of solution; however, its basic principle of operation involves a piston-type action. This principle by nature produces a pulsating effect in the stream of solution being discharged from the pump. This pulsating effect gives rise to an uneven and discontinuous application at the point of treatment. At best, it provides an intermittent application of the fluoride solution, or slugging. In addition to this, the quantity of solution is so small that good dispersion is practically impossible.

The second problem is related to the possibility of syphoning the fluoride solution from the source of supply, due to direct connection to the main, in the event that a vacuum is created at the point of injection. This could occur as a result of pipeline breakage, abnormal hydraulic conditions at the point of application, check valve failure, etc.

There are a variety of systems that have been used in an attempt to eliminate these two problems of assured continuous uniform and safe application of a fluoride solution.

One type of system entails the use of two pumps with an additional solution mixing tank. The one pump is a metering pump, which is used to accurately meter the concentrated fluoride solution to the second tank, into which dilution water is continuously added. This diluted solution is in turn injected into the pipeline by a second pump, which is of the higher capacity turbine or centrifugal type.

Because the discharge of the pri-

mary metering pump is allowed to feed open to the second tank, the problem of syphoning is minimized to the capacity of the second solution tank. Dispersion has been improved by the continuous injection of the larger volume of dilute solution. With this system, the second solution tank and the secondary pump must also be constructed of corrosion resistant materials. This adds further cost to the installation and maintenance of the system.

Another type of system which is used to improve dispersion, but does not eliminate the possibility of syphoning, consists of a pipe section in parallel with the mainline pipe. The inlet and outlet of this parallel pipe section must be placed across a restriction in the main line that will cause a low-velocity flow through this section. The restriction may be a pipe fitting, valve, or other mainline restriction, or may be artificially produced by a pitot tube arrangement.

The concentrated fluoride solution is injected into the upstream end of the parallel pipe section. The low velocity of flow at the point of application provides a reasonable degree of dispersion. Although this system reduces the effect of slugging, it does not positively eliminate it. Also, experience has shown that a corrosion problem is encountered in the parallel pipe section unless suitable materials of construction are used again making for added cost in both installation and maintenance.

Another system used eliminates both these problems and deserves special comment both from the standpoint of simplicity of design and positive safety features. This system was developed by Kalamazoo, Mich., which began fluoridation in 1950. During the initial months of this program they obtained daily test results that indicated a variation in fluoride concentration, which was at first attributed to inaccuracy of the feeding equipment. Tests later proved this variation to be caused by the slugging of fluorine solution due to the characteristic pulsating discharge from the chemical feed pump.

The Kalamazoo Water Department then began experimentation to devise a system which would eliminate this variation in concentration as well as eliminate the possibility of syphoning. The system devised involves use of the existing chemical feed pump to feed hydrofluosilicic acid into a small mixing and dilution tank. The metered acid is discharged into the top of the tank, into which dilution water is added at a regulated rate.

The constant strength dilute solution is withdrawn from the bottom of the tank and injected into the main line using a water ejector. This diluted solution is withdrawn from the bottom of the tank by the vacuum created in the ejector and is further diluted by the water flowing through the ejector. Excellent dispersion is attained, as this dilute solution is discharged to the point of application continuously.

The dilution tank is designed to maintain a constant volume of dilute solution and to automatically and positively maintain a constant rate of withdrawal. An air break between the pump discharge line and the top of the dilution tank positively eliminates the possibility of syphoning concentrated fluoride solution into the treatment system.

Solubility Factor

The physical property of the fluoridation agent which affects the use of solid form compounds is solubility. The solubility of any solid form compound is dependent on (a) the temperature of the solution water and (b) the time of contact allowed between the compound and the solution water.

The potentially adverse effect of each of these factors can be eliminated by proper design and adequate temperature control (again at added installation and maintenance cost). The time factor can be overcome by proper mechanical design so that the flow rate is low enough to insure sufficient dissolving time at the operating temperature. The temperature factor can be overcome by providing adequate temperature control for the chamber in which the solid material is dissolved.

The solubility factor dictates the quantity of water that is required to dissolve a unit weight of any solid form compound at some specified temperature. Therefore, in effect, it dictates the minimum quantity of aqueous solution of the solid form compound that must be prepared and subsequently metered to the point of application by the chemical feed pump.

Although the exact quantity of solution that would be required is dependent on the selected operating conditions, the relative volumes required to contain one pound of available fluoride are shown pictorially in Figure 3. In the interest of comparison, the volumes of hydrofluoric acid and hydrofluosilicic acid required to contain one pound of available fluoride are also shown. The volume of each of these acids is independent of the operating temperature, as they are purchased in solution form.

It is essential to point out that without adequate temperature control, difficulty in maintaining a controlled operation may be experienced with the use of solid form compounds. Should the temperature of the water fall below the required minimum in the solution preparation mixing tank, undissolved material will pass from

TABLE 2

Composition Factors of Fluoridation Agents

% Comp.	Factor	% Comp.	Factor	% Comp.	Factor	% Comp.	Factor
100	1.000	80	1.250	60	1.666	40	2.500
99	1.010	79	1.266	59	1.695	39	2.564
98	1.020	78	1.282	58	1.724	38	2.632
97	1.030	77	1.299	57	1.754	37	2.703
96	1.042	76	1.316	56	1.786	36	2.778
95	1.053	75	1.333	55	1.818	35	2.857
94	1.064	74	1.351	54	1.852	34	2.941
93	1.075	73	1.370	53	1.887	33	3.030
92	1.087	72	1.389	52	1.923	32	3.125
91	1.099	71	1.408	51	1.961	31	3.226
90	1.111	70	1.429	50	2.000	30	3.333
89	1.124	69	1.449	49	2.041	29	3.448
88	1.136	68	1.471	48	2.083	28	3.571
87	1.149	67	1.493	47	2.128	27	3.704
86	1.163	66	1.515	46	2.174	26	3.846
85	1.176	65	1.538	45	2.222	25	4.000
84	1.190	64	1.563	44	2.273	24	4.167
83	1.205	63	1.587	43	2.326	23	4.348
82	1.220	62	1.613	42	2.381	22	4.545
81	1.235	61	1.639	41	2.439	21	4.762

the tank to the point of application. Obviously this could give rise to a potentially hazardous condition.

With a saturator tank any variation in temperature will cause a corresponding variation in the concentration of the solution entering the point of application and will result in inaccurate dosage of fluoride. Of the two solution preparation systems, adequate temperature control is more critical when using the saturator.

Of the two more commonly used solid form compounds, adequate temperature control is more critical with the use of sodium silicofluoride than with sodium fluoride, because the former has a wide range of solubility over the normal range of operating temperatures. However, the absence of adequate temperature control using either of these mechanical methods for the preparation of aqueous solutions of the solid form compounds presents undesirable and potentially adverse conditions in the treatment operation.

Another factor that must be taken into consideration when considering the use of sodium silicofluoride is its corrosive nature: a saturated solution has a pH of 3.5 to 4.0. Saturated solutions of sodium fluoride, on the other hand, will normally have pH values slightly on the alkaline side. Therefore, materials more highly resistant to corrosion must be used for handling solutions of sodium silicofluoride.

Chemical Factors

The chemical property of the fluoride ion which affects the application operation is its potential to react with certain other ions present in the water, forming insoluble compounds. This property will affect the solution preparation operation and the selection of the point of fluoride application.

In respect to the solution preparation operation, the solid form compounds are primarily affected. Inasmuch as solid form compounds must be dissolved in water, any interfering ion present in sufficient concentration will react with the fluoride ion to form an insoluble fluoride compound. For example, calcium and magnesium ions present in sufficient concentration will react with the dissolved fluoride ions to form insoluble calcium fluoride and insoluble magnesium fluoride.

Should precipitation occur in this operation, insoluble fluorides may pass into the treatment system. Once in the system they may settle out in the low points in the distribution system, where they may cause plugging and increase water main maintenance. If they should (due to unusual conditions) re-dissolve, it would occur in a random manner, causing fluctuations to occur in the fluoride ion concentration throughout the system; or they might pass through in slugs, causing an even more undesirable condition.

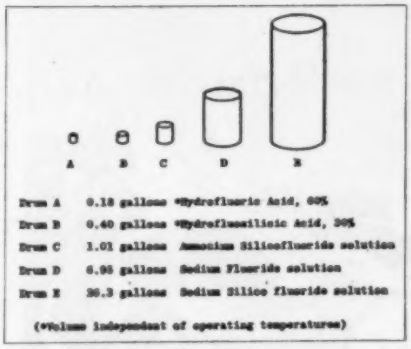

A
B
C
D
E
Drum A 0.18 gallons *Hydrofluoric Acid, 60%
Drum B 0.40 gallons *Hydrofluosilicic Acid, 30%
Drum C 1.01 gallons Ammonium Silicofluoride solution
Drum D 6.06 gallons Sodium Fluoride solution
Drum E 36.3 gallons Sodium Silico fluoride solution
(*Volume independent of operating temperatures)

Fig. 3—RELATIVE VOLUMES of aqueous solution to contain 1 lb of available fluoride; solution temperature approximately 60°F.

This precipitation reaction will occur at any time the individual concentrations of the fluoride ions and the interfering ions exceed the limiting concentrations. As such, the occurrence of the reaction is dependent on varying relative concentrations of each; therefore, the limiting concentration of each of the interfering ions in the solution water is dictated by the concentration of the fluoride ions in the fluoride solution, or vice versa. In cases where the minimum concentration of fluoride ion required to make a solution preparation operation practical gives rise to the production of insoluble fluorides, the solution water must be treated to reduce the concentration of the interfering ions to the limiting value.

In such cases, this would increase the over-all cost of the fluoridation operation, both from the standpoint of providing adequate solution water treatment facilities and the continued operating cost of the treatment. Both these costs are related to the quantity of solution water that would have to be treated and this in turn is related to the solubility of the selected solid form compound.

Because these interfering ions are constituent ions of several of the water treatment chemicals, the point of fluoride solution application must be carefully selected at those installations also using chemical treatment. At such installations, the fluoride solution should not be applied prior to any treatment operation designed to remove undersirable constituents by either coagulation, precipitation, or absorption. The simple rule to remember is that any treatment designed to remove other substances will usually remove fluorides. Following this rule, the fluoride solution should be applied as the final step in the treatment before the water is discharged to the distribution system.

Chlorination used for the purpose of disinfecting the water in the final step in the treatment will not remove fluoride. Because there is no chemical reaction that occurs between chlorine and fluoride, these substances can be added simultaneously to accomplish purification an dmluoridation in one operation prior to discharging the water to the distribution system.

Selection of Fluoridation Agent

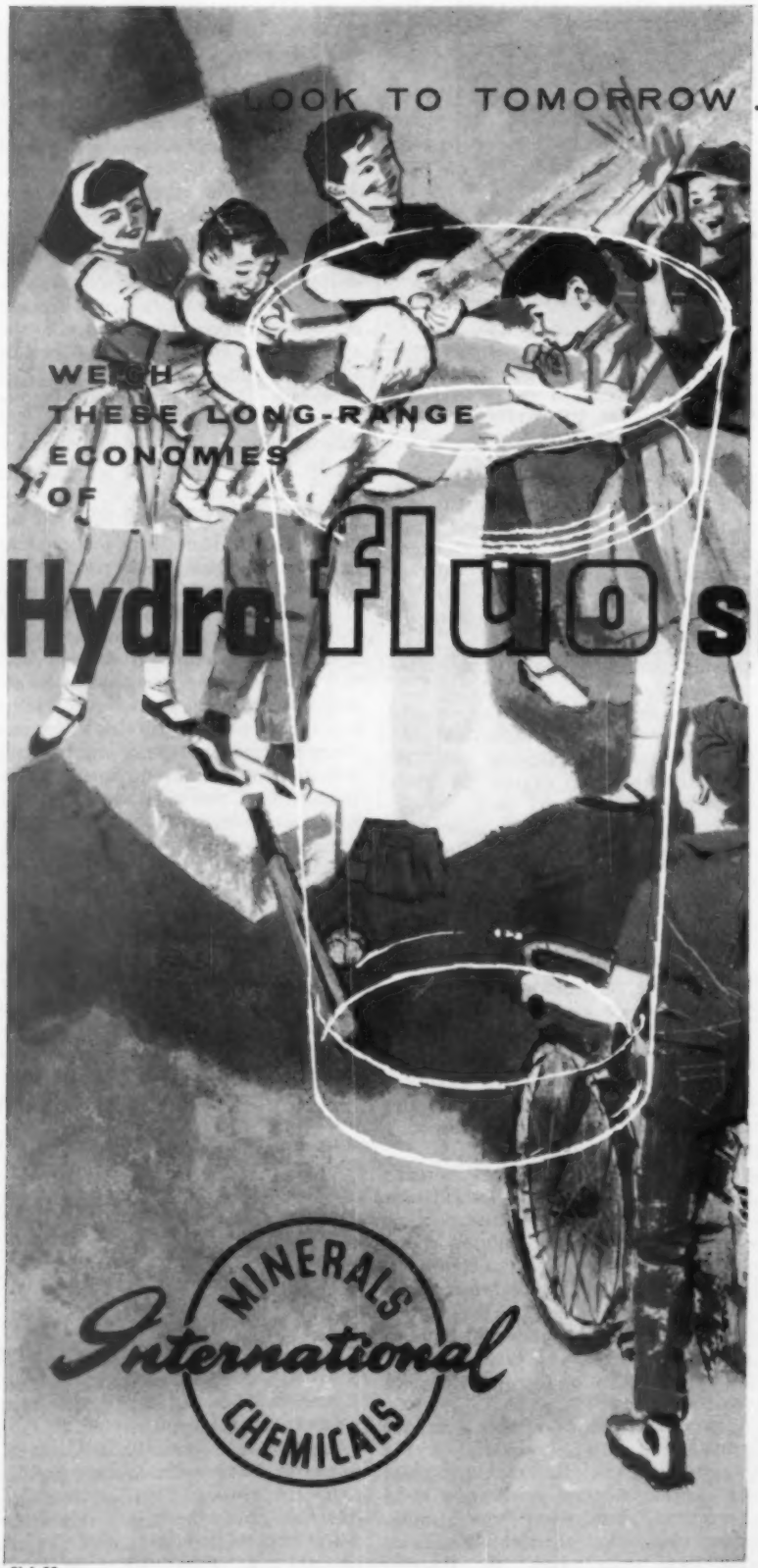
The selection of the particular fluoridation agent to be used in the fluoridation operation is, in the final analysis, made after a comparison of the over-all cost picture for each agent. This picture is divided into two parts; namely, (a) the immediate cost, which is the initial cost of the equipment including installation charges; and (b) the operating cost, which includes the equipment maintenance cost, the chemical cost, and, when considering solid form compounds, the solution preparation cost.

After taking all cost factors under consideration, it will become obvious that, generally speaking, the use of a solution form compound is, in the long run, more economical than the use of a solid form compound.

In addition to the definitely lower installation and operating costs associated with the use of solution form compounds, they offer additional practical operating advantages. These advantages are:

1. They are purchased at exact solution strength.
2. They require no preliminary preparation.
3. Their use involves simply direct feed from the container in which they are received.
4. Their lower handling requirement provides greater safety to operating personnel.

On the other hand, solid form compounds, although purchased at exact composition, cannot be fed directly into the system without some preliminary preparation. This preparation is not only costly but also invloves constant supervision to control the two variables associated with the operation. At best the use of solid form compounds is troublesome from a practical operational viewpoint.



when you weigh fluoridation costs

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International hydrofluosilicic acid typically runs 25% acid solution with a guaranteed minimum of 23% H_2SiF_6 by weight. Every shipment passes the challenge of particular quality controls. And behind all this: Unending research to further improve high purity.

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Wherever you're located, the far-ranging network of International plants underwrites quick delivery of hydrofluosilicic acid by tank truck, tank car or customer's drums. As for the future, *International's* production know-how and facilities will keep it coming in years ahead.

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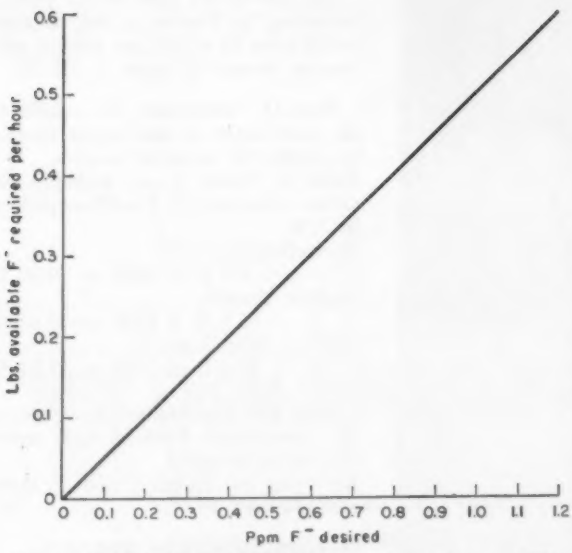


Fig. 4—AVAILABLE FLUORIDE ion requirement per 1000 gpm flow rate.

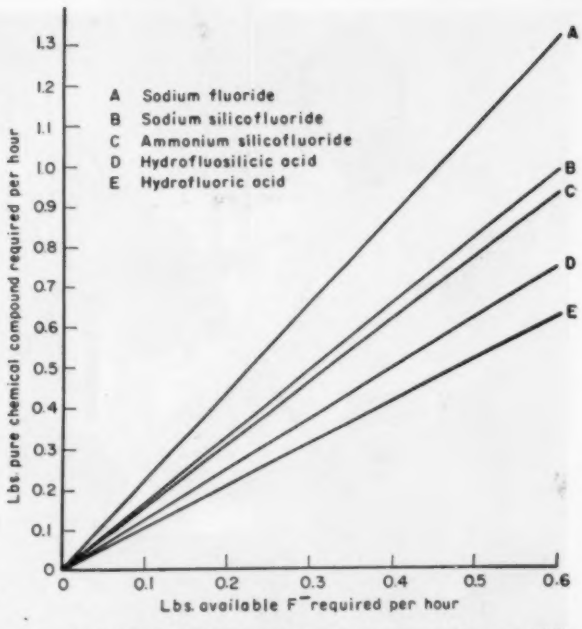


Fig. 5—PURE FLUORIDE compound requirements per 1000 gpm flow rate.

It is sound reasoning based on fundamental, technical, and engineering principles that gives the corollary: "It is always easier to feed a prepared solution than to prepare a solution for feeding." This corollary holds true for any application of a chemical compound that must be exactly proportioned to the quantity of water being treated.

It is this reasoning that is the basis of the recommendation that solution form compounds should be used in applied fluoridation. Further, recognizing the greater degree of hazard associated with the use of hydrofluoric acid as compared to hydrofluosilicic acid, it is further recommended that first consideration be given to hydrofluosilicic acid. It is recognized that there will be instances where the relative transportation costs will prohibit the use of either of the solution form compounds and in such cases the use of adequate temperature control is required to maintain uniform concentration of the fluoride solutions prepared from solid form compounds.

Safety Measures

As a protection against dust, the operator should wear a dust respirator, a transparent eye shield, and rubber gloves when handling solid form compounds. When handling solution form compounds a transparent eye shield and rubber gloves should be worn as a protection against splashing.

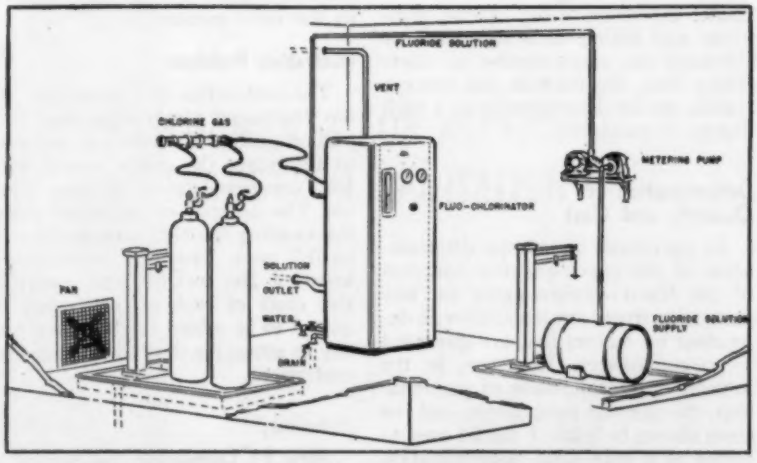
Although the feed hoppers of some dry feeders are equipped with a dust collector, dusting can be greatly reduced by the careful handling of the dry material during the filling operation. The same hazard can also be greatly reduced when filling a saturator, by slitting the top of the bag and emptying the contents while the open end is immersed beneath the surface of the water. The usual precaution of washing the hands after each filling operation is a good safety practice to be followed.

Sampling and Testing

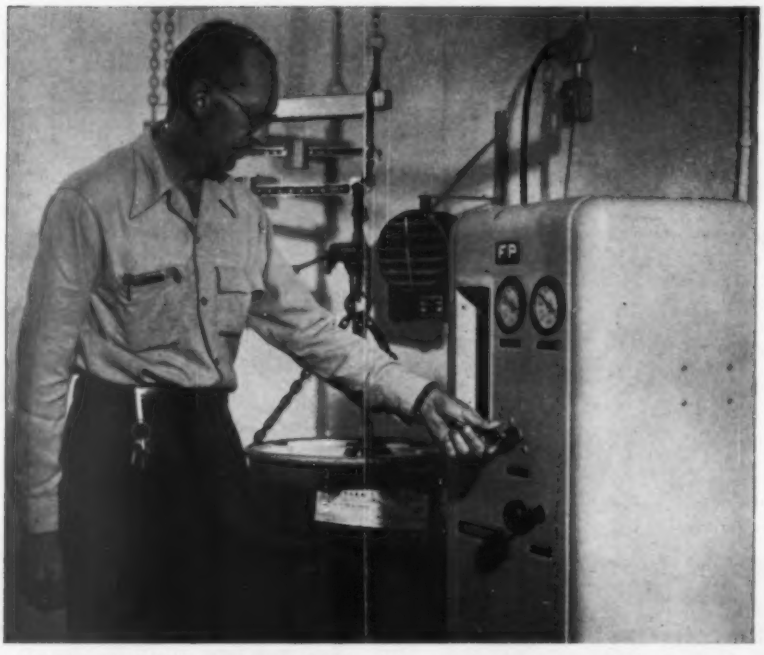
An important phase of applied fluoridation is the determination of the quantity of fluoride ion present in the water, both at the plant and at selected points throughout the distribution system. This information must be obtained and recorded at any plant practicing fluoridation.

The standard tests* used to determine the quantity of fluoride are based on the reaction between fluoride ion and the zirconiumalizarin lake in an acid solution. The color resulting after a definite time of contact is dependent on the quantity of fluoride present in the sample under test. The

*Standard Methods for the Examination of Water, Sewage and Industrial Wastes," 10th Edition, Amer. Pub. Health Assn., New York, N. Y. (1955)



INSTALLATION diagram of a Fischer & Porter fluo-chlorinator system.



SINGLE MACHINE performs double duty as simultaneous chlorinator and fluoridator.

intensity and hue of the color is either measured photometrically or compared visually with color standards. The visual comparison can be made using permanent color standards and commercial slide comparators, or by preparing color standards at the time of test and making the comparison with the use of Nessler tubes.

The accuracy of the test is affected by the presence of certain other ions, which may be present in the water in sufficient concentration to interfere with the intensity and hue of the final color. In some water supplies this interference can be eliminated by diluting the sample with water; in others the sample must first be distilled, the test being made on the distillate. However, using careful technique and taking steps to reduce or eliminate the concentration of interfering ions, the fluoride ion concentration can be determined with a high degree of accuracy.

Determination of Quantity and Cost

As previously stated, the determination of the exact quantity and cost of the fluoridation agent for any particular treatment installation is dependent on factors that are governed by circumstances. However, in the interest of completeness of presentation, the percent composition and the costs shown in Table 1 can be used to arrive at a very close approximation of these values. Briefly, this involves four distinct steps, in the order given:

Step I: Determine the weight of fluoride required.

Step II: Determine the weight of the pure form of the agent needed to supply the fluoride.

Step III: Determine the weight of the commercial form of the agent that must be added.

Step IV: Determine the cost of the agent.

A practical illustration will demonstrate the effectiveness of the systematic use of the graphs and tables in obtaining the rapid solution to a problem. (Hydrofluoric acid and ammonium silicofluoride have not been included, but would be calculated in the same manner.)

Illustrative Problem

The authorities of a municipal water treatment plant supplying 0.96 million gallons of water per day wish to fluoridate the entire supply to a total concentration of 1.0 ppm fluoride. The analysis of the water shows the existing fluoride concentration to be 0.1 ppm. They are interested in knowing the weights and comparative costs of each of the agents required to be added to the water each day to attain the desired fluoride concentration.

Solution:

Step I: Determine the weight of fluoride required.

The ppm fluoride that must be added are:

1.0 ppm − 0.1 ppm = 0.9 ppm

Referring to Figure 1, the fluoride which must be added per million gallons to obtain 0.9 ppm = 7.5 lb.

Step II: Determine the weight of the pure form of each agent needed to supply the required fluoride.

Refer to Figure 2 and multiply the values obtained for 1 million gallons by 0.96

Hydrofluosilicic acid .....
9.4 lb x 0.96 = 9.02 lb

Sodium fluoride .....
16.5 lb x 0.96 = 15.84 lb

Sodium Silicofluoride .....
12.3 lb x 0.96 = 11.81 lb

Step III: Determine the weight of the commercial form of each agent that must be added.

Referring to Tables 1 and 2, these weights are:

Hydrofluosilicic acid, 30% .....
9.02 lb x 3.33 = 30.04 lb

Sodium fluoride, 95% .....
15.84 lb x 1.05 = 16.63 lb

Sodium silicofluoride, 99% .....
11.81 lb x 1.01 = 11.93 lb

Step IV: Determine the cost of each agent.

Referring to Table 1, this is:

Hydrofluosilicic acid .....
30.04 lb x 0.06 = $ 1.80

Sodium fluoride .....
16.63 lb x 0.14 = $ 2.33

Sodium silicofluoride .....
11.93 lb x 0.09 = $ 1.07

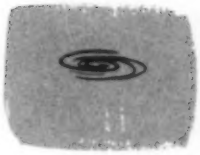
Many communities obtain their water from ground water supplies using deep well pumps. This water may be pumped directly into the distribution system.

The output from each well may be treated separately, or the combined output from several wells may be treated. In the case of separate treatments the equipment is generally located in the pump house, for combined treatment the equipment may be located in one of the pump houses or at some centralized point.

Depending on the size of the community and the location of the wells, there may be one or more treatment installations. Because the water treatment depends on the flow rate, and deep well pumps are normally rated in gallons per minute, Figures 4 and 5 are presented as a convenience in calculating the requirements for installations of this nature. All calculations using these graphs follow the same stepwise procedure as outlined and presented in the illustrative problem.

COMPLETREATOR

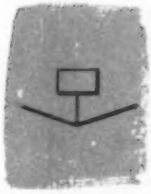
SPIROVORTEX



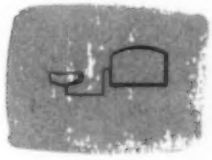
DORRCLONE CLASSIFIER

NEW FROM DORR-OLIVER

DEGRITTING CLARIFIER/CLARIGESTER

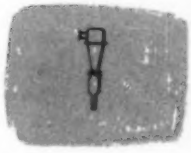


During the past three years . . . 7 new developments from Dorr-Oliver to revitalize the solution of municipal and industrial sanitation problems. In scope, these new processes range from preassembled small sewage treatment plants to water desanding systems. These seven new developments are the outgrowth of Dorr-Oliver's continuing sanitary research program . . . and still newer developments to keep pace with modern trends are coming.

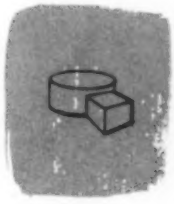


DENSLUDGE DIGESTION

DORRCLONE DESANDER



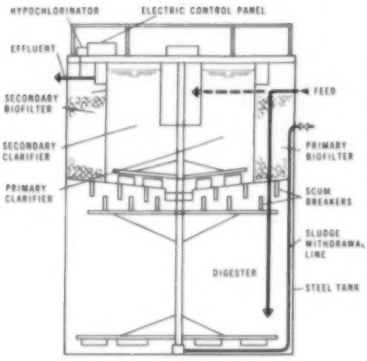
PERIFILTER



7 DEVELOPMENTS FOR MUNICIPAL AND INDUSTRIAL SANITATION

BULLETIN NO. 6043

THE DORR-OLIVER COMPLETREATOR



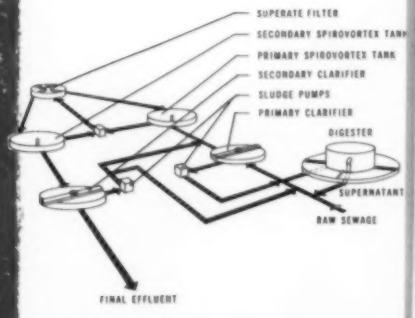
. . . complete sewage treatment in a **single** tank for a population equivalent of 150 persons. The CompleTreator consists of a Dorr DuoClarigester surrounded by two stages of high rate trickling filters and two recirculation pumps, all shipped assembled in a single steel tank. Average daily capacity is 15,000 gallons and 90% BOD and suspended solids removals can be realized. The CompleTreator is ideally suited for housing developments, motels, restaurants, service stations, schools, military installations and domestic type wastes from industrial activities.

Bulletin No. 7315.

THE DORR-OLIVER SPIROVORTEX SYSTEM

. . . incorporating the Superate Filter . . . for complete treatment of domestic sewage and intermediate treatment of industrial wastes. The system is based upon the same theory which underlies the activated sludge process and is capable of producing the same degree of purification with B.O.D. removals exceeding 90%. An ideal System for expansion of existing facilities, it will produce an excellent settling sludge, regardless of whether the plant is overloaded or operating under normal conditions. The System therefore eliminates bulking of sludge and resulting increase of solids in the plant effluent.

Bulletin No. 7314.



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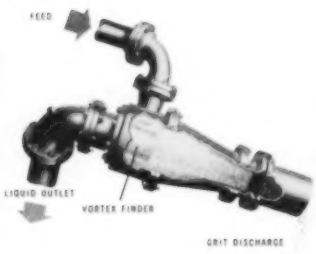

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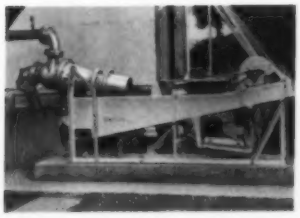
. . . for degritting sewage . . . a new method for removing and washing grit from raw sewage and settled sludge. The DorrClone is a compact cylindro-conical classification unit utilizing centrifical force in place of gravity. Full scale installations have proven this unit is applicable to the degritting of raw sewage prior to primary sedimentation; the degritting of primary clarifier underflow prior to Densludge Thickening; and the washing of Detritor Collecting Tank discharge. In each of the above applications, the DorrClone will make a separation at about 150 mesh or 104 microns on sand.

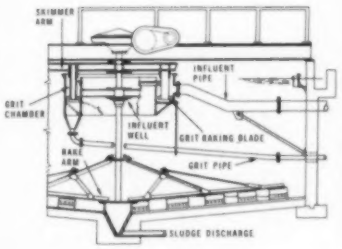
Bulletin No. 2508.

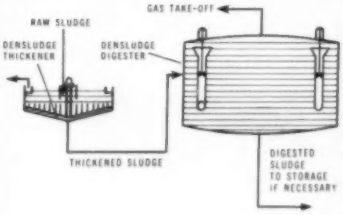


THE DORR-OLIVER DEGRITTING CLARIFIER AND CLARIGESTER

. . . a new combination unit providing positive mechanical grit removal with conventional clarification in a single tank. Applicable for maximum flows of 0.45 to 1.75 MGD, this new design incorporates an annular well around the Clarifier feed well. Adaptable to both Dorr Type 'A' Clarifiers and Dorr Clarigesters, 20' to 40' in dia., this new design will remove troublesome grit from the raw sewage without the need for costly and separate grit handling facilities.

Bulletin No. 6412.





THE DORRCO DENSLUDGE DIGESTION SYSTEM

. . . for modern sewage digestion at 20-30% of conventional capacity requirements. The new Dorrco Densludge Digestion System, already proven in full-scale treatment plants, is a new method of digesting sewage sludge that makes possible a reduction of up to 80% in digester capacity requirements compared with conventional systems. The basic operation of the Densludge Digestion System involves concentrating sludge ahead of digestion in a specially designed rugged Thickener, then digesting sludge in a Digester equipped with high-capacity draft tube mixers.

Bulletin No. 6262.

THE DORRCLONE DESANDING SYSTEM

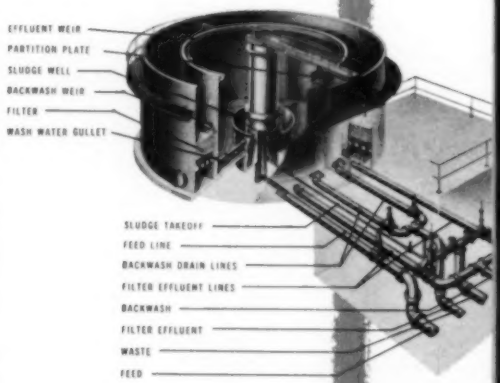
. . . a new, continuous, low-cost method for removing sand and silt from water supplies. Essentially the Desanding System consists of a DorrClone separator, underflow chamber, and feed pump. It is identical to the DorrClone Classifier described on page 2 except that the mounting is vertical instead of horizontal. This DorrClone unit will make a separation in the range of 500 mesh (30 microns) to 200 mesh (74 microns); and it has been determined that the sand particles larger than 200 mesh are those which cause the most trouble in a distribution system.

Bulletin No. 2507.

DORRCO PERIFILTER SYSTEM

. . . new "unitized" water treatment. The new unique design of the Dorrco PeriFilter System provides installation of pre-treatment unit and annular sand filter in same tank. Additional units are added as demand increases. With a single PeriFilter System, the filter is split in half so that finished water is continually produced, even during backwashing.

Bulletin No. 9042.



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Sewage Effluent Reclamation

by P. H. McGAUHEY

Director, Sanitary Engineering Research Laboratory, University of California at Berkeley, Calif.

DURING the past few years there has been an increasing awareness in California that the traditional "once-only" usage of water is a luxury the state can ill afford. Funds have therefore been made available for research on the public health and engineering problems involved in salvaging water, and at least one major conference has been called to discuss the administrative, legal, and economic aspects of waste water reclamation. The State's water problems, however, are of such magnitude, and the proposals for their solution so challenging, that scale size alone has often tended to obscure the importance of waste water reclamation. Nevertheless, a healthy interest in the possibility of reclaiming sewage effluents has been manifest throughout the past five years.

What Is Sewage Reclamation?

In a broad sense "sewage reclamation" might be defined as the purposeful upgrading of the quality of sewage with the intent of making it re-usable by agriculture, industry, or the public. Such a definition has by no means been standardized, and the term "reclamation" is sometimes applied to the actual utilization of sewage effluent which for some other reason has undergone suitable treatment. In any event the term does not apply to incidental reclamation achieved by dilution of sewage discharged into watercourses for the purpose of disposal, even though water from the stream may be suitable quality for beneficial use. Nor does it apply to the treatment of sewage for the mere purpose of disposal.

Historically, advancing sanitary standards of growing population has made it necessary to consider public health, aesthetics, and the rights of other water users in the matter of sewage treatment. Such considerations determine the degree of treatment to be imposed in any situation, but the purpose of treatment has always been to achieve whatever minimum modification of sewage is required before it may legally be thrown away. Fortunately, the upgrading of sewage in order to meet the requirements of disposal lessens, and sometimes accomplishes, the task of reclamation. In other cases, however, it commits a community to a program inimical to sewage reclamation in the immediate future.

Need For Re-Use of Water

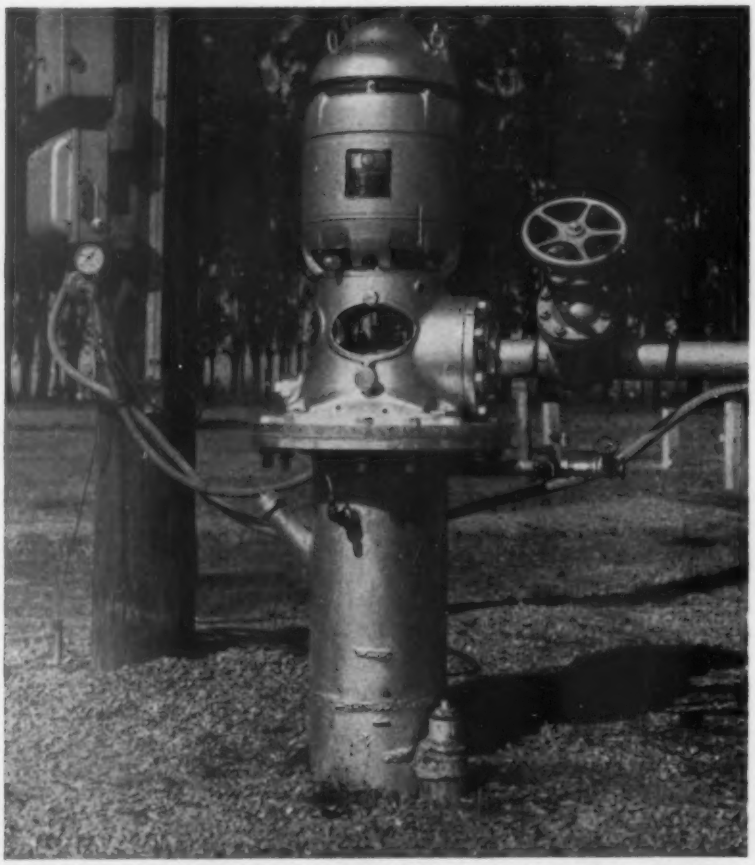
The quantity and distribution of available water with respect to the population concentrations in California is the principal reason why sewage effluents might well be reclaimed for local re-use. Although the studies which led to the California Water Plan show that there is enough water in the state for everyone if it is wisely conserved and developed in an intelligent manner, the fact remains that development of the Water Plan calls for time, while serious water shortages and ground water overdrafts are immediate in many areas of California. The details of this story of rapidly declining ground water, sea water intrusion, and water shortage have been told so often that they need not be repeated here. They do, however, underscore the need for multiple usage of the water which is presently available.

There are reasons in logic also why sewage effluents should be reclaimed and re-used. If sewage were discharged without any treatment whatsoever, we should be sending a 2000-ton train of water, on which we lately spent a great deal of money in purifying, to transport a single ton of organic solids. Worse yet, in the more common case of well treated sewage, one good burro could carry all that is required of this half million gallons of water. Furthermore, we throw away the train at the end of a single trip. It is in line with our heritage of waste, but it is without parallel in the history of transportation.

Sewage as a Source of Water

If we are seriously to consider sewage as a source of reclaimable water it is important to know how much water is involved, and what is its availablity to potential users. When the total consumptive use of water is considered, it is easy to depreciate the importance of that portion finding its way into sewers from domestic and industrial users; and this has often been done. It has conservatively been estimated[1] that 6 million acres of new irrigated cropland will have to be brought into full production by 1975 if we are to maintain our present standards of nutrition. Presumably this acreage will lie in the 17 western states, and will require an average of not less than 3 acre-feet of water per acre per year —or 18 million acre feet annually. The 1950 census showed this area to have a population of about 34 million. Assuming that the present population is, say 40 million, and that 60 percent of these live in sewered communities, the total sewage flow would be but 3 million acre feet per year, or 1/6 the agricultural need for new water if the entire sewage flow could be reclaimed. When allowance is made for that portion of the population located in areas or surplus water, in mountains, and in other localities remote from irrigable land, it is probable that considerably less than 10 percent of the agricultural need for water in the west could be met by sewage reclamation. This is certainly the case in California where 90 percent of the water goes into irrigation of crops. Assuming the other 10 percent to be domestic supply, of which 70 percent reaches the sewers, reclamation of the entire sewage flow from California's urban centers would add but 8 percent to the water available for irrigation.

This line of reasoning simply means that the production of water for agricultural use can hardly be the principal goal of sewage reclamation. For other potential uses the story is more favorable. On the basis of California's 13 million people, and assuming that 80 percent of the population lives in cities, domestic sewage equals about 40 percent of our presently estimated 2 million acre-feet of annual overdraft on ground water basins for all uses. This is an important amount of water. Making allowance for sections of the state where reclamation of sewage for agriculture or for ground water-replenishment seems patently uneconomical, it appears that sewage reclamation might be feasible in an amount equal



RECHARGE WELL for reclaiming sewage treatment plant effluent by direct injection into underground water bearing stratum at Richmond, Calif.

to say 20 percent of our present ground water overdraft.

Using something other than the vast needs of agriculture as the yardstick of water quantity it can again be shown that presently wasted sewage represents an appreciable volume of water. For example, approximately half a billion gallons of water are wasted to the ocean each day after a single usage by the inhabitants of California's two greatest concentrations of population. This might represent the combined yield of 350 12-inch wells each producing 1000 gpm continuously; it is enough water to produce 7800 tons of steel daily at the normal figure of 64,000 gallons per ton; or to meet the waterneeds in refining of 615,000 barrels of petroleum per day even if cooling water was used but once; it represents 0.85 percent of the total industrial use of water in the entire United States; and, yes, it would irrigate 100,000 acres of land even if nearly half of it were lost to evaporation during storage.

From the foregoing rough comparisons we may understand that in speaking of sewage reclamation we are indeed speaking of an important amount of water, even though much greater amounts may be needed by agriculture.

Who Shall Make Use of Reclaimed Sewage Effluent?

The fact that sewage plant effluents occur in population centers suggests at once that the activities of these centers are the logical ones in which reclaimed effluents might be re-used. Specifically, this means in industry, in local irrigation, and in domestic supply. The first two of these are the most promising because they can use reclaimed water directly after much less treatment than would be necessary for a domestic water supply. In fact aesthetic considerations as well as cost of refinement of water quality preclude the direct re-use of sewage effluent in the home. It may, however, be used by the public to recharge ground waters, and thus later become a part of the water supply, or to irrigate parks and golf courses, or, as in the case of San Francisco, to maintain recreational ponds as well. In large cities some use may be made of reclaimed sewage in peripheral agriculture or in the maintenance of pasture land for dairy cattle not currently producing milk, or for beef animals, but industry seems the logical user. In the vicinity of smaller cities, however, grain crops, orchards, and pasture land may be the principal outlet for reclaimed sewage effluent.

Why Have We Been Slow to Re-Use Waste Waters?

A number of factors enter into our past and our present failure to reclaim sewage effluents for beneficial use. Valid technical, engineering, economic, and legal problems as well as psychological considerations have

TABLE I

Comparison of Estimated Cost of Reclaimed Sewage and Cost of Alternate Water Supply in the Southwest

Location	Cost of Water	Cost of Reclaimed Sewage	Use
Golden Gate Park San Francisco, Calif.	$66/acre ft	$21/acre ft	Lawn & Shrub irrigation ornamental lake
Grand Canyon, Ariz.	$550/acre ft	$120/acre ft	Lawn irrigation
Los Alamos, New Mexico	$92/acre ft	$24/acre ft	Power plant cooling water
Carlsbad, New Mexico	—	$25/acre ft	Irrigation of Golf Course
Santa Fe, New Mexico	$75/acre ft	$49/acre ft *	Irrigation of Golf Course
Las Vegas, Nevada	$30/acre ft	$27/acre ft	Irrigation of Golf Course
Jal, New Mexico	—	$69/acre ft	Irrigation of Golf Course
Big Springs, Texas	$51-$105/acre ft	$15/acre ft **	Boiler feed water

* Includes cost of delivering 3½ miles.
** Includes only part of treatment cost.

only recently been defined and partially solved. In fact, our national psychology of wastage of all second-hand things has done much to delay vigorous attention to the practical problems. Coupled with this has been a curious discontinuity in our concept of water usage, which causes many engineers and public officials to think of the collection, transportation, treatment, and distribution of water supply as one complete package; while the re-collection, transportation, and re-treatment of that same water is an unrelated job of scavanging.

In 1930, Goudey[2] demonstrated that a highly treated sewage could be safely applied to the ground water by surface spreading, and in 1949, Arnold, Hedger, and Rawn[3] found ground water recharge with treated sewage to be both technically and economically feasible. A general lack of interest in sewage reclamation, however, delayed further scientific investigation and thus limited the possible methods of reclamation essentially to irrigation of crops not meant for human consumption in a raw state. Inasmuch as such croplands are generally inaccessible to large sewage treatment plants, reclamation by this method is of limited feasibility. Until quite recently it was believed that direct recharge of ground waters was impractical because of clogging due to suspended matter in sewage effluents; and it was feared that pathogenic bacteria might travel long distances with moving ground water.

Direct re-use of sewage plant effluents by industry was likewise given little serious consideration. Industry's traditional pride in its concern for economics only could not be refuted by advocates of sewage reclamation in the absence of experience. In adidtion, effluent available at a central treatment plant is expensive to transport back upstream to the site of potential users. The city itself looks with dismay on the prospects of laying another conduit in a paved street already underlain with various utilities. And it is a considerable nuisance to keep two water systems separated within a plant.

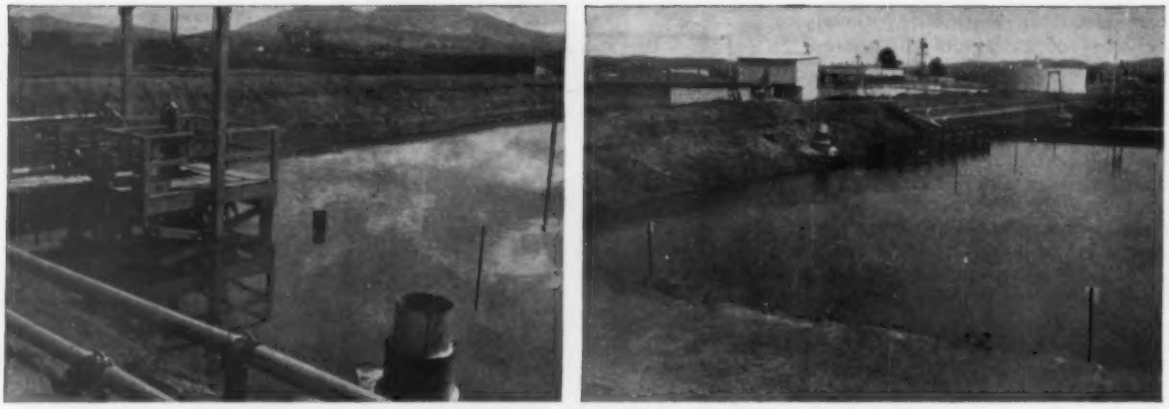
Ventures into sewage reclamation are further inhibited by the fact that the economics of waste water utilization are not known. In any event, why pay the cost of sewage reclamation when it is cheaper and permissible to mine out existing ground waters, regardless of the long term consequences to water resources. The whole concept of water rights is a deterring factor to sewage reclamation. Who, for instance, owns water recharged underground at public expense? And what restriction may be placed upon its withdrawal from an already overpumped ground water basin?

A unique situation has contributed to the lack of progress in sewage reclamation in Southern California, where the largest volume of plant effluent is available. In its simplest terms it evolves around two questions: why use Colorado River water as long as the ground water lasts at $5 per acre foot? and why go to the expense of reclaiming sewage as long

TABLE 2

Summary of Direct Re-Use of Sewage Plant Effluents in the Western States

Location	Nature of Principle Usage
ARIZONA	
Bagdad	Mining Industry - ore dressing
Hayden	" " " "
Inspiration	" " " "
Miami	Mining Industry - ore dressing; Park Irrigation
Morenci	" " " "
Tiger	" " " "
Grand Canyon	Power Plant-Cooling Water; Lawn Irrigation
CALIFORNIA	
Bakersfield	Irrigation - animal feed crops & Cotton
Delano	" " " " "
Fresno	" " " " "
Hanford	Irrigation - animal feed crops & sorgum
Mt. Vernon (San. Distr.)	Irrigation - animal feed crops & cotton
Ontario	Irrigation - animal feed crops & grain
Pomona	Irrigation - animal feed crops & citrus
San Bernardino	Irrigation - animal feed crops & orchards, berries
Tulare	Irrigation - animal feed crops & cotton
Taft	Irrigation - cotton, maize seed
Wasco	Irrigation - cotton, maize seed & cotton
Barstow (USMC Depot)	Irrigation - golf course
El Cajon	Irrigation - golf course
El Toro (Marine Base)	" " "
Camp Pendleton (Marine Base)	Irrigation - golf course
San Francisco (Gold. Gate Park)	Irrigation - park and lawn, lake
Twenty-nine Palms (Marine Base)	Irrigation - recreational fields
Escondido	Quarrying Industry - Sand & Gravel Washing
Fontana	Steel Industry - process & cooling water
San Bernardino	Power Plant - cooling water
NEW MEXICO	
Hurley	Mining Industry - process water makeup
Carlsbad	Irrigation - golf course
Jal	Irrigation - golf course
Los Alamos	Irrigation - golf course & recreation fields
Santa Fe	Irrigation - golf course
Los Alamos	Power Plant - cooling water
TEXAS	
Amarillo	Oil Refining Industry - cooling water
Big Springs	Oil Refining Industry - cooling water & boiler feed water
Dallas	Power Industry - boiler feed water
Abilene	Irrigation - animal feed crops
Kingsville	Irrigation - animal feed crops & cotton
Lubbock	Irrigation - grains, cotton
San Antonio	Irrigation - animal feed crops
San Antonio	Lake for wildfowl
NEVADA	
Las Vegas	Irrigation - golf course, lawns
UTAH	
Provo	Steel Industry - process water



TWO VIEWS of Concordia, Calif., sewage reclamation ponds employing algae.

as we are paying for Colorado River water which we are not presently using? In such a situation, there is little choice but to wait until a more appropriate time. In the meantime the pressing problems of sewage disposal will probably cause expenditures to which it may be economically unfeasible at a later date to add other expenditures for reclamation. This is another reason why we have been slow to reclaim sewage.

In general, it might be said that we have been slow to re-use waste water because we have just not been sufficiently interested in doing so, or in solving the problems necessary to make it possible, as long as we can get along without it.

What Is Known About Sewage Reclamation?

As previously noted it was demonstrated in Los Angles in 1930 that highly treated sewage effluents can be safely used for ground water replenishment; and again in 1949 engineers in this same area found ground water recharge by spreading to be economically and technically feasible. Their recommendation that the method be used to reclaim 125 million gallons of sewage per day on eight spreading basins in the Los Angeles area was not followed, but the experimental spreading grounds at Azusa from which they[3] drew their conclusions have continued to perform satisfactorily, and represent today the principal example of sewage reclamation by spreading.

Within the past five years experiments in sewage spreading on soils much finer than the Azusa gravels have been conducted on a field scale at Lodi, and on a smaller scale at Richmond, Calif., by researchers of the University of California. These studies have been sponsored by the California State Water Pollution Control Board, the State Department of Public Health, the U. S. Public Health Service, and the University itself. Among the many findings was the fact that sewage can be applied to the five types of soil investigated at a rate of about one-half acre-foot per acre per day; and that intestinal bacteria are removed from the liquid within the first four feet of travel through the soil.

Since 1951 the California State Water Pollution Control Board has also financed a 3-year study of sewage reclamation by direct injection into ground water. From this study a practical method of recharge well operation was developed and the public health safety of such a reclamation procedure was demonstrated. Bacterial travel with moving ground water did not exceed 100 feet even though the settled sewage introduced carried very high concentrations of organisms. Other studies financed by the Board and still in progress have brought together existing evidence that grains, grass land, orchards, golf courses, etc. may be safely irrigated with seawge plant effluents. Other evidence shows that such effluents may be economically used by industry for cooling water and other plant needs.

From economic studies in progress at the University of California at Rerkeley, it is concluded that when the cost of treating sewage to the degree demanded by public health and water pollution is charged to such considerations, reclaimed sewage plant effluents can in many cases be profitably used in irrigation in competition with water selling for $6 to $10 per acre-foot. Furthermore it can compete with the $6 to $24 per acre-foot paid by industry for much of its boiler feed water and cooling waters. In more arid areas it has already been shown that water reclaimed from sewage may be economical even if all treatment costs are charged against the value of the water. Table 1 presents comparative costs of new and reclaimed water at a few places in the southwest.

While the foregoing conclusions by no means summarize all that we know about sewage reclamation, they may serve here to point up the fact that sewage effluents may be reclaimed by ground water recharge, or by direct re-use on the land or by industry; and that such reclamation is technically and economically feasible as well as consistent with public health considerations. The things we do not know about sewage reclamation are mostly those which can be learned only from experience, and from a willingness to make the necessary political and legislative arrangements.

Present Status

Some positive developments in sewage reclamation and utilization have taken place in California and elsewhere in the southwest in recent years. Many of these have been undertaken without the benefit of scientific knowledge, and generally in localities where a water shortage is immediate or where the need is urgent to dispose of sewage effluents in the most economical fashion acceptable to health or pollution control authorities. In 1954, 74 communities and 32 public and private institutions in California were reported[4] to be using sewage effluents for irrigation of crops and pasture. At the same time, the use of effluents for some type of surface spreading or ponding was reported by 78 communities and 36 institutions in the state. Only a few of these were sizeable communities; in fact the total population contributing to the sewage used for irrigation was

but 250,000. Most had no well engineered reclamation procedures, hence it is probable that in terms of what we are doing in planning sewage reclamation the figures are deceptive, including a great many places simply concerned to be rid of sewage plant effluents where no receiving water is available. In larger communities such as Fresno and Bakersfield, California, reclamation is deliberate rather than incidental, but in almost no case has a treatment plant been designed specifically for water reclamation. The single exception in California, as far as I know, is the plant in San Francisco's Golden Gate Park, which was designed specifically to produce an effluent suitable for a recreational pond and for irrigation of shrubs and grass.

In general, and this is true of all of the southwest as well as of California, sewage reclamation is what we do with existing treatment plant effluents, rather than what we do to sewage to make water suitable for further beneficial use.

Direct re-use is perhaps the only method of sewage reclamation currently in practice. An extensive report[5] published by the California State Water Pollution Control Board in 1955 and summarized in Table 2 shows that industry makes use of sewage treatment plant effluents in 7 communities in Arizona; 4 in California; 2 in New Mexico; 4 in Texas; and 1 in Utah. Irrigation of crops, pastures, lawns, golf courses, etc. with sewage effluents was reported at 2 places in Arizona; 17 in California; 1 in Nevada; 4 in New Mexico; and 4 in Texas. San Antonio, like San Francisco, utilizes sewage effluent in a recreational lake. No instance of direct injection into water bearing strata is reported in the literature.

Prospects for the Future

Although extensive field and laboratory investigations have shown that the reclamation of water from sewage is feasible by known techniques, its widespread adoption is likely to depend upon a number of factors which are slowly becoming recognized. One of these is a revised concept of sewage and sewage reclamation; another is the idea that the sewage disposal and water reclamation aspects of sewage treatment are not necessarily synonymous.

In the matter of new concepts is the full realization that treating sewage to the degree required by regulatory agencies is in reality a procedure which restores some degree of quality to a water in which the city already has a large investment. This water must then be recognized as a resource which is valuable not only because it is capable of re-use, but also because it exists within the city and is immediately available. Furthermore, it must be recognized that the importance of this resource is not diminished by the fact that in volume it does not equal the needs of agriculture, or by the fact that elsewhere there exists unused water which may some day become available to the city.

From the standpoint of reclamation versus sewage disposal it seems probable that in the future sewage reclamation will develop as planned reclamation rather than as simple marketing of sewage plant effluent now being wasted to the ocean. Because of favorable economic factors and freedom from legal involvements this reclamation will undoubtedly develop more rapidly around direct re-use in industry and in irrigation, than around ground water replenishment. Reliance on sewage treatment to reclaim water, as at present, results in serious drawbacks. The effluent is concentrated at a point of poor availability to the user, especially the industrial user. In addition, there is a tendency to require the user to take effluent continuously. This restricts the crops which may be grown as well as the land use in agriculture, and involves impounding problems in industry. Both seriously depreciate the value of reclaimed effluent and may make the process uneconomical. Then too, there is always the danger of losing sight of the public health interest in sewage treatment and to become unprepared properly to cope with a situation in which some catastrophic event, such as a chemical spill, renders the sewage temporarily unreclaimable.

Successful sewage reclamation plants of the future may be expected to be divorced from the sewage treatment plants in the manner suggested on various occasions by A. M. Rawn, of the Los Angeles County Sanitation Districts. They will be unit plants of appropriate size placed along the sewer system at points strategically located with respect to industrial users. Some portion of the sewage will therefore always remain in the sewer and will require treatment prior to disposal.

While data on the economics of reclaiming water from sewage are fragmentary, it seems evident that economic considerations will not rule out sewage reclamation, although the vagaries of cost may be a delaying factor. As ground waters approach depletion, and as the cost of transportation of water from more distant sources is felt, there will be an upward revision of the value of water. The time required for completion of various segments of the California Water Plan may also increase the value of water by reason of local shortage. All of these factors may combine to enhance the value and importance of reclaimed sewage effluents.

The future of sewage reclamation might well be summarized by the concensus of representatives of federal, state, and local governments; industry; agriculture; and other interests who took part in a conference on waste water reclamation held in Berkeley in 1956. It was generally felt that there exists no undue legal obstacles to the reclamation and re-use of water from sewage; that reclamation is technically feasible; and that existing water and irrigation districts are so constituted that the development of administrative machinery is not a deterent to practical waste water reclamation.

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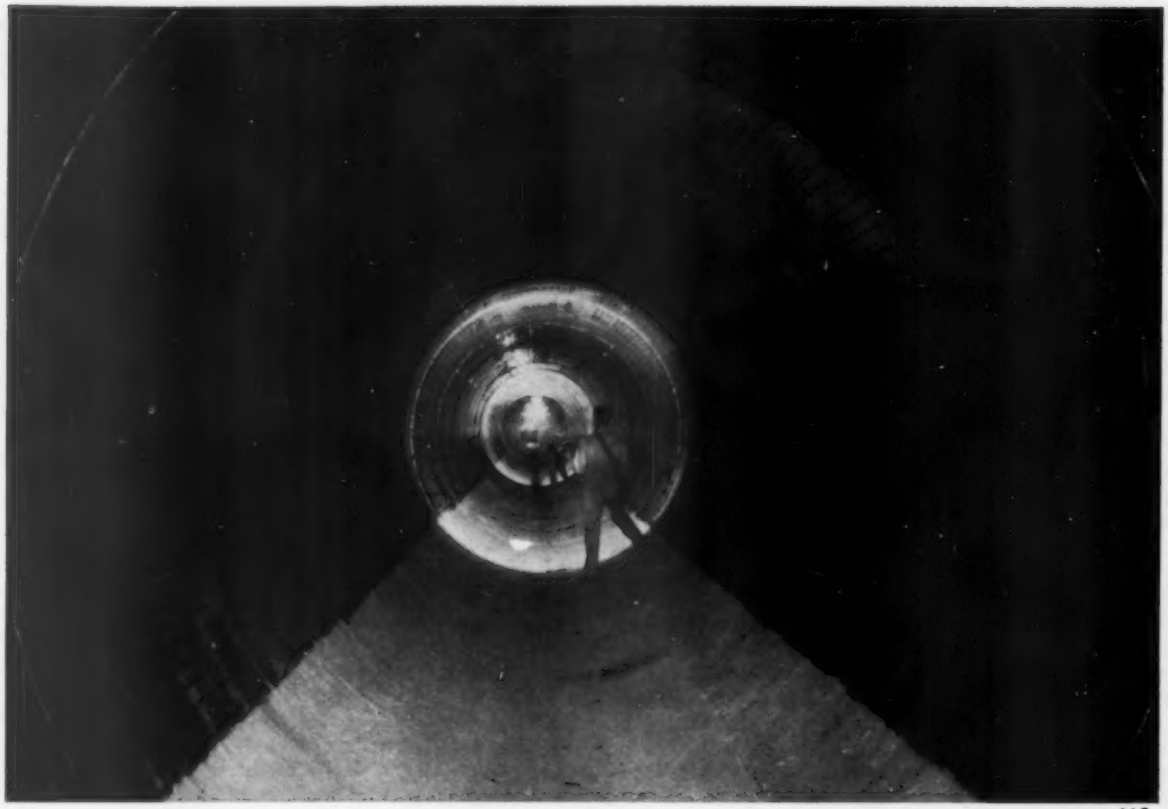

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This Sewer will go a Long Way

Not only will this 9¾-foot outfall sewer extend eight miles, but it will go a long way in years of trouble-free service. The engineers who designed it say that it will still be functioning perfectly in the year 2000.

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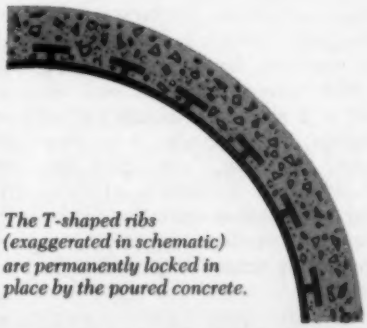
Because of obvious and substantial savings such as this, millions of square feet of T-Lock are now in use in progressive municipalities from coast to coast. These include Los Angeles; Topeka; Wichita; Sioux City; Shreveport; Washington, D.C.; San Diego; Mansfield, Ohio; Huntington, W.Va.; Hutchinson, Kan.; and Orange County, Calif. T-Lock Amer-Plate is also on current specifications for many other municipalities. For complete list of users and specifiers, plus technical data and a typical specification, write:



The T-shaped ribs (exaggerated in schematic) are permanently locked in place by the poured concrete.

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Concrete Sewer Production

Methods employed by the City of Los Angeles to protect masonry sewers against attack by hydrogen sulphide gas.

by LYALL A. PARDEE and E. G. STUDLEY

Respectively, City Engineer and Engineer of Sewer Design, Los Angeles, Calif.

HYDROGEN SULFIDE gas is present at times in the atmosphere of practically all sanitary sewers which flow as open channels within the separate sewer system of the City of Los Angeles. Severe corrosion of unprotected concrete has occurred due to acid attack from the oxidation of hydrogen sulfide to sulfuric acid.

For many years the City has tested linings and coatings of corrosion resistant materials, under accelerated and actual sewer conditions. However, to date, few have proven to be sufficiently impermeable to protect concrete indefinitely.

The present design practice of the City specifies that either polyvinyl chloride plastic liner plate or clay lining blocks be used to protect the exposed inner surfaces of larger sewers or reinforced concrete construction. Extensive construction of sewerage facilities using these protective linings has been and is now being completed for the City.

History

The history of large outfall sewers serving the City of Los Angeles has been one of corrosion and of continual expense to combat this corrosion. The first outfall was constructed to the ocean at Hyperion in 1894. Five years after completion, serious sulfide deterioration was reported. After twelve years of service, the outfall was badly deteriorated. The City had grown so in the meantime that this sewer could not properly serve the new areas of the City. This outfall was completely abandoned in 1908 after only fourteen years of service.

In 1906, the Central Outfall was constructed with an increase in capacity and so located as to serve territory not tributary to the first outfall sewer. By the time the North Outfall was constructed in 1924, the capacity of the Central Outfall had been exceeded. At the time the North Outfall was placed in operation, the use of the Central Outfall was discontinued. Since 1937, portions of the Central Outfall have been reconditioned and placed in use again but only at a cost of over a million dollars required for its rehabilitation, including replacement of corroded mortar and brick from the upper half of the sewer. Corrosion of the Central Outfall Sewer is now being controlled by positive ventilation throughout the length of the outfall by means of a ventilation station located at the Hyperion Treatment Plant.

Prior to the construction of the North Outfall Sewer in 1924, a Special Sewerage Commission reported on the "partial disintegration of masonry by sewer gases" in the Central Outfall Sewer and recommended that "the North Outfall Sewer be built in such a manner as to resist disintegration from sewer gases as far as this is practicable." It was also the recommendation of this Commission that "the outfall sewer be constructed of acid-resisting materials."

In order to decrease the cost of the North Outfall, certain economy measures were adopted, including the elimination of acid-proof joint material between the clay lining blocks and the elimination of reinforcing steel except at certain special locations. After 12 years of operation of the North Outfall Sewer, a 6-mile downstream section was inspected, and large areas were found devoid of the clay lining block. The concrete, thus exposed, was corroded and soft, the maximum depth of such corrosion being approximately 5 inches. Little or no additional corrosion has occurred since 1936 in this section of the outfall, due to the adequate ventilation system conceived and installed at that time. Since its inspection in 1936, in addition to the cost of ventilation, approximately 1.7 million dollars have been spent for the construction of reinforced concrete blanketing at critical locations. This was occasioned partly by the interior deterioration of the outfall and partly by its location and lack of steel in the original construction.

A Study of Corrosion Protective Materials

The Department of Public Works of the City of Los Angeles, in the early 1930's, through its Bureaus of Engineering and Standards, initiated a testing program for corrosion protective products. This program has been continued on a considerably augmented and expanded scale until at the present time approximately 25 items are being tested concurrently on a long term basis. It is the practice of the Bureau of Enigneering to specify only those materials approved by our Bureau of Standards.

Exposure manholes throughout the system at selected locations of severe corrosion are used to test paint and protective coatings, protective liners and in some cases corrosion inhibitors in concrete.

In the ever widening search for economical protection against corrosion, long term tests are carried on for many promising products. As has unfortunately been the case, however, by far the vast majority of these have proved incapable of affording permanent protection to concrete. Results of these tests are released only to the manufacturer or his representative.

Basic Philosophy

On the basis of past history and the continuous testing program, a basic philosophy encompassing the design and protection of sewers has evolved within the Bureau of Engineering which may be briefly summarized as follows:

1. Except for isolated exceptions, sewers are designed to flow as open channels and hydrogen sulfide is usually present in some degree in the sewer atmosphere.

2. The generation of hydrogen sulfide and its oxidation to acid is dependent upon the composition and activity of the microbic population of sewers. Forecasts of variation in these populations have not as yet been made with assurance.

"T-LOCK" Amer-plate plastic liner, and reinforcing steel on inner form of 8'-3" sewer.

3. Hydrogen sulfide generation, release and oxidation causes acid corrosion of concrete and unprotected concrete cannot be depended upon to withstand this attack.

4. Of all the methods advanced to date for corrosion protection and/or prevention, there appear to be only two which have been successfully and economically applied to sewers, and these are (a) protective linings mechanically bonded to the concrete and/or the use of clay pipe, and (b) submersion, i.e., surcharging the sewer so that it will always operate under head.

5. The Bureau of Engineering specifies the use of clay pipe exclusively for sewers 30 inches in diameter and smaller; for sewers 30 inches in diameter or over, clay pipe (if available) and/or protectively lined concrete pipe are specified. The liner covers all exposed concrete above the low water surface.

This design criteria anticipates that the larger sewers must have an assured life of at least 100 years in order to justify providing capacity which will not be required for a number of years in the future. It is the Bureau's opinion that every economical means should be included in sewer construction to assure this maximum length of life and that the adoption of speculative or untried methods to either reduce or eliminate the corrosive conditions should not be depended upon.

Plastic Liner Plate

Research in the development of plastic liner dates back to the early 1930's when the manufacturer, the Amercoat Corporation of South Gate, Calif., began studies of controlling corrosive attack by the use of inert plastic lining. Many laboratory tests have since been conducted, both by the manufacturer and by the City of Los Angeles. All of the early testing of this liner, called by its trade name "Amer-Plate", was conducted within a sewage pumping chamber located in the city of Coronado near San Diego. This chamber, which was subject to severe sulfide attack, was maintained as a testing area for a number of years until disintegration caused its abandonment.

In 1947, "T-Lock" Amer-Plate was installed in the highly corrosive atmosphere of a pumping chamber of the City of San Diego at Mission Beach. For this pioneer application, the liner was fabricated in one-foot squares, molded on a laboratory press. Periodic inspection of this installation shows no deterioration to date (10 years later) of either the liner material or the concrete it protects. The presently manufactured liner plate is made of polyvinyl chloride plastic, is about 0.060 inches thick, and is provided with parallel and projecting "T" shaped anchoring ribs, 2½ inches on center, molded integrally to the back of the liner plate. Concrete poured against the back of the liner surrounds the T-lock and provides a permanent mechanical anchorage. These liner plates are now manufactured in sheets 4 feet by 8 feet, and may be fusion-welded to make larger sheets. Field joints are made by applying welding strips of the plastic which by means of hot-air guns are fusion-welded to the sheets. The continuity of the plastic sheet is excellent. Minute holes can be detected electrically with a spark tester at the completion of construction.

Installations of "T-lock" Amer-plate within the City of Los Angeles, since 1949, have shown no perceptible deterioration to date. It is evident that protection will be afforded by the material for an extremely long period of time. Samples of the plastic liner removed to date show that a slow hardening occurs. This may be caused by loss of plasticizer or other changes. It should be emphasized, however, that the changes that have occurred have not been detrimental and that no basis exists for determining how much time must elapse until detrimental hardening occurs.

In January, 1949, the inlet and outlet chambers of a large inverted siphon were lined with approximately 7600 square feet of "Amer-plate," and at the same location, about 320 linear feet of 42-inch diameter R.C.P. air line for the conveyance of the corrosive atmosphere across the siphon was also lined. In April, 1949, over 3,000 linear feet of 60-inch diameter and 6-foot by 4-foot box structure were lined in the reconstruction of a portion of the West Los Angeles Interceptor Sewer. In January of 1950, over 4800 linear feet of 30 and 36-inch interceptor sewer was lined during the construction of the Los Angeles Street Interceptor Sewer. In 1953 and 1954, the La Cienega and San Fernando Valley Relief Sewer, approximately 10.5 miles long, varying in size from 48-inch diameter to 8 ft.—3 inch semi-elliptical section, was lined with plastic liner plate for all but 1.5 miles of its length. The remaining section was lined with clay liner blocks.

Under authority of the City Council, the Board of Public Works in 1955 retained Hyperion Engineers, a

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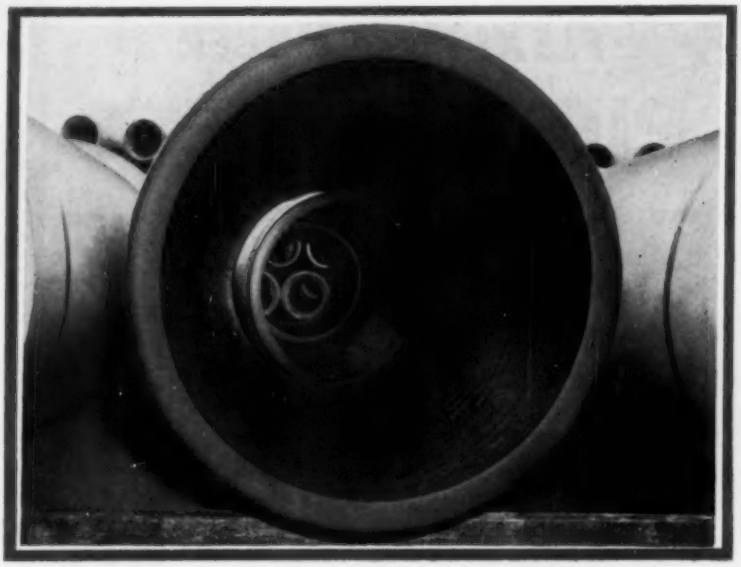

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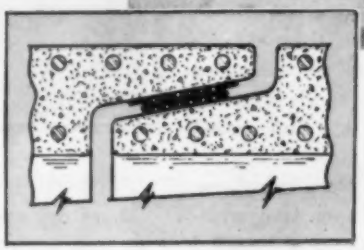

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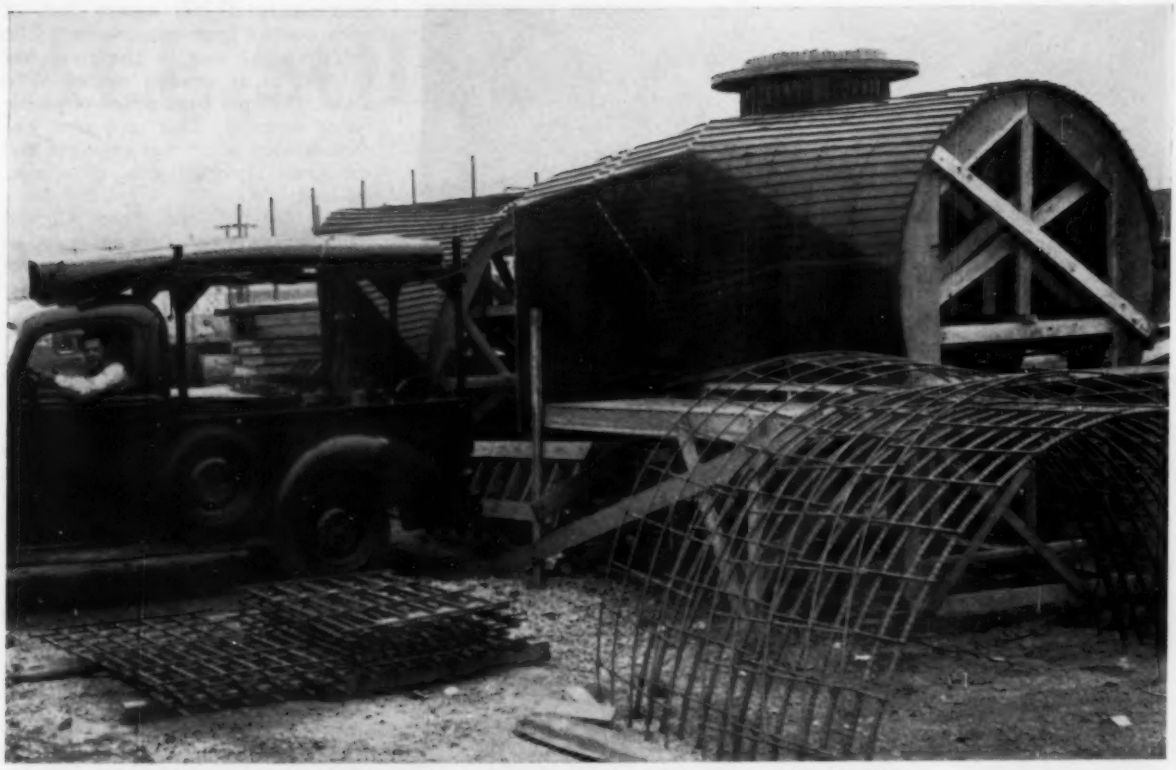

AMER-PLATE plastic liner in place on forms for a transition structure.
The "ridges" visible are the "T-Locks", which will be embedded in the poured concrete.

joint venture of Holmes & Narver; Daniel, Mann, Johnson and Mendenhall; and Koebig and Koebig; all consulting engineers of Los Angeles, to prepare plans and specifications for the North Central Outfall Sewer. This new outfall sewer will augment the existing two outfall sewers now in service and will provide outfall capacity for the City of Los Angeles until the year 2000.

After investigating and inspecting all pertinent examples of corrosion-resisting lining and after reviewing the theories of hydrogen sulfide generation elimination and/or reduction, these consultants concluded, in a letter to the Board of Public Works prior to final design, that "Anything that can be economically done to make the structure durable indefinitely should be constructed into it." They further stated that "It is the Hyperion Engineers' recommendation that the North Central Outfall Sewer be lined with a suitable vinyl plastic to a proper design depth below minimum anticipated flow conditions for its *entire length* except at siphons where the sewer will run full continually."

The Hyperion Board of Consultants, established to review and approve plans and specifications prepared by Hyperion Engineers, and of which the City Engineer of Los Angeles is a member, voted by majority in favor of the Hyperion Engineers' recommendations to protectively line the sewer. The Board of Public Works subsequently adopted their recommendation.

When finished, the North Central Outfall Sewer will represent the largest single installation of "Amerplate" lined sewer thus far specified, amounting to over 825,000 square feet.

Clay Lining Blocks

Clay lining blocks with mortar joints were used in the construction of the principal interceptor and outfall sewers between the years 1924 and 1930. With the exception of the North Outfall Sewer, the majority of these installations are at locations of moderate acid attack and remain in generally good condition, the tile intact, with sound concrete beneath. The mortar joints, however, are obviously the weak points since they are vulnerable to attack. Sulfide corrosion has caused them to become mushy, expand in volume, and unless ventilation is effected, the loss of the joint material eventually will permit entry of acid behind the tile liners.

As a result of the unsatisfactory experience with mortar joints, the City of Los Angeles has long tested other joint materials. The clay lining blocks themselves have been improved in recent years by reducing their permeability. Cement mortar has been replaced with an approved cold air-drying synthetic rubber base sewer joint compound, hot coal-tar, or plastic sewer joint compound. With the advent of these acid-resistant joint compounds and when used with the improved clay lining blocks, it is believed the combination offers effective sulfide corrosion protection.

Clay lining blocks are individual pieces ¾"x9½"x24" in size, conforming to the inside sewer curvature, with three locking lugs extending the full length along the back of the block. These lugs are so shaped as to firmly seat in the concrete pour.

As mentioned above, a lining conforming to the improved requirements was used in a 1.5 mile section of the La Cienega and San Fernando Valley Relief Sewer.

Cost of Protection and Value Accrued

To be in accord with the concepts of engineering economics, the value accrued from built-in acid resistance should equal or be greater than the

WELDING STRIP being applied to joint of plastic liner with hot-air gun.

cost of the acid-resistant material installed. It is the opinion of the Bureau of Engineering, on the basis of construction bids, that the cost of building acid resistance into sewers is not excessive in view of (1) the benefits derived, (2) the assurance of increased life of the sewer and (3) the positive elimination of other means of attempting to provide control or eliminate corrosive conditions.

It is immediately apparent that the benefits resulting from acid resistance are for the most part intangible and cannot be evaluated momentarily with any degree of accuracy. The cost of acid resistance, however, is easier to estimate, although, in some cases this cost is not as clear cut as could be desired.

In those pipe sizes where vitrified clay pipe is used to provide acid resistance, the incremental additional cost for protection may be easily derived; for costs for clay pipe and cement pipe are available and from the mutitude of installations resulting cost analyses may be compared.

For sizes where clay pipe is not available and where plastic sheet or clay liner block has been used to provide acid resistance, data from only a few projects are available from which comparative bid figures can be obtained. Prior to 1956, bids for large diameter sewers, with one exception, were taken only for lined conduit with no optional unlined alternate allowed.

In April, 1956, bids were received for Relief of Venice Interceptor Sewer, Unit A, a 51-inch diameter sewer of approximately 2400 feet in length. Upon instruction from the Board of Public Works, bids were received on both a lined and unlined basis. Approximately 31,000 square feet of acid-resistant liner was involved. The differential cost in the bids was $15,086, or an amount equivalent to about $0.49 per square foot of plastic lining material. This unit cost was considerably below that expected and the lined alternate was, of course, selected.

The bids for the North Central Outfall Sewer were received in 1956 for each of its two units of construction on the following basis: (1) a plastic lined base bid and (2) an unlined conduit (except for isolated locations) augmented by 2 inches of sacrificial concrete. In total the two units of this sewer are comprised essentially of 9′-6″ diameter conduit which total approximately 42,000 feet in length and of which the majority is of monolithic tunnel construction. There are about 455,100 square feet of liner plate in Unit I and 370,600 square feet in Unit II. While comparison is possible only between acid-resistant material and the additional 2-inch thickness of sacrificial concrete, it is nevertheless interesting to examine the differential costs. In addition, it should be emphasized that the additional friction resulting from corrosion was not considered in the sacrificial concrete alternates so that the same size conduit was included for both alternates.

For Unit I of the North Central Outfall Sewer, the low construction bid for the plastic lined conduit was $6,196,691, the low construction bid for the conduit with sacrificial concrete was $5,946,566; the differential was, therefore, $250,125, or an equivalent of $0.55 more per square foot of plastic liner. Correspondingly, the low bids for Unit II of this facility were $4,930,000 for plastic lining and $4,812,000 for sacrificial concrete. The differential was $118,000, or an equivalent of $0.32 more per square foot for plastic lining material. It should be noted that Unit I is almost entirely of tunnel construction while Unit II has a significant amount of open trench construction.

As has been previously mentioned, the lined alternate as recommended by the City Engineer and the City's consulting engineers, is now under con- tion in 1958.

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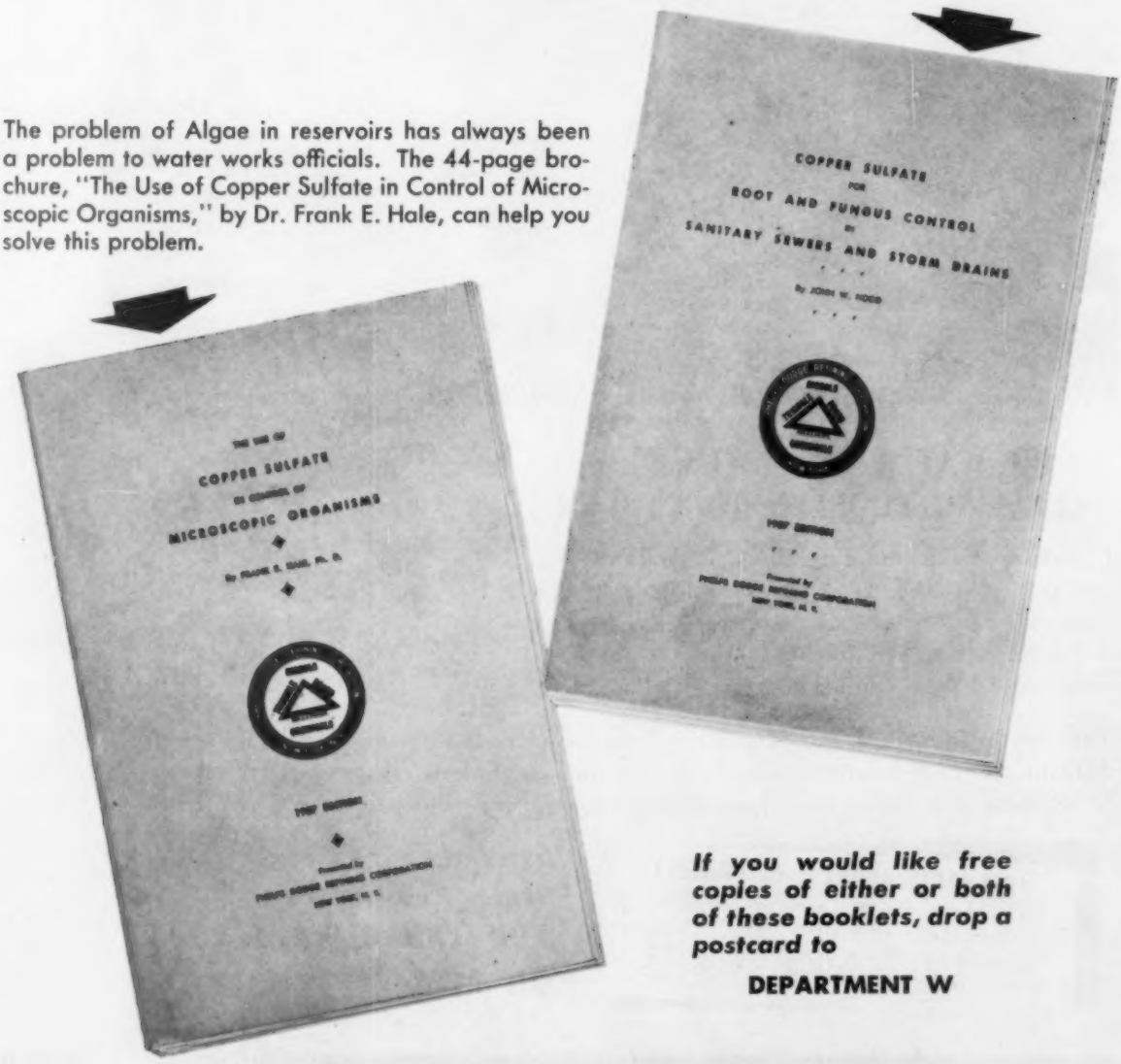
If you have read Mr. Hood's article on root control in sewers in this issue, you will probably want additional information.

Mr. Hood prepared this 24-page brochure, "Copper Sulfate for Root and Fungus Control in Sanitary Sewers and Storm Drains," especially for you. It can add immeasurably to your knowledge of how to combat this problem.

The problem of Algae in reservoirs has always been a problem to water works officials. The 44-page brochure, "The Use of Copper Sulfate in Control of Microscopic Organisms," by Dr. Frank E. Hale, can help you solve this problem.



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Copper Sulfate

Its Use for Root Control in Sewers

by JOHN W. HOOD

Supt. of Sewage Treatment, Ridgewood N. J.

Following the publication of the original article on this subject which appeared in the March 1942 issue of Water & Sewage Works, many requests for supplemental information have been received from City, Town and State Officials in the United States; Canada; South America and Great Britain. These correspondents included state health department and city engineers; mayors and commissioners; city managers; superintendents of sewerage systems and sewage treatment plants and pump stations; also foresters; arborists; restaurateurs and private citizens. This response revealed the widespread interest in the subject matter, and the extent to which the related problems caused by root infiltration had been experienced. This widespread interest was further reflected in publication of the APWA Special Report No. 5 (1948) and in 1949, the Phelps Dodge Refining Corp. treatise on the use of copper sulfate for root and fungus control in sanitary sewers and storm drains; the latter bulletin was issued in a revised edition in 1954.

The original article was also reprinted in the annual Reference Number of *Water & Sewage Works*, and was revised and reprinted in The Reference Number in 1949. Because of the importance of this "tool" for the maintenance of root-free sewers, the author was requested to again revise and update the article for publication here.

■ SANITARY, aesthetic and economic problems are caused by root infiltration and pipe line obstruction. Public officials and private citizens alike are all too frequently found apathetic to proposed preventive measures, the exceptions being those who have already had experience with flooded cellars and interrupted sewer service (the latter all too frequently occurring nights, Sundays and holidays!) Many adult citizens are frank to state that they have never given the matter a single thought—they just don't know.

Why Clean Sewers

Sewer systems need adequate cleaning and maintenance to prevent:

1. Back up affecting business and residential premises and possible public health hazards and property damage.
2. Loss in carrying capacity of pipe lines.
3. Formation of obnoxious, lethal and combustible gases which are a hazard to the safety of sewer maintenance men and a potential hazard to property.
4. Deterioriation of sewer lines and structures caused by the by-products of biochemical action occurring in obstuctions.
5. Change in the character of sewage which adversely affects treatment processes.

The unstable and decomposable character of sewage solids dictates the importance of free flowing pipes. Scouring velocities are produced by adequate gradients and by the intermittent discharges from contributing buildings. An innovation for dealing with the deposition of solids in sewers is the 'Sewer Ball' developed by A M Rawn of Los Angeles County San. Dist. and Sydney Preen of Long Beach, Calif. It is operated by the upstream head of water, and simplifies the problem of grit and sediment removal.

Causes of Stoppages

Stoppages will occur in long flat graded trunk lines where scouring velocities are absent. Grit deposition and the standing of solids are common under such conditions.

Roots are also a common cause of obstruction; in practice they are difficult to deal with by mechanical means.

Fungi are prolific in sewage collection systems and generally are found in association with 'reducing' conditions. They obstruct free flow in pipes and contribute to the generation of lethal and explosive by-product gases from the sewage substrate.

Conditions Resulting from Stoppages

Carbon dioxide (CO_2), the 'choke damp' of the mines is evolved from the initial degradation of carbonaceous compounds; hydrogen sulphide (H_2S) or rotten eggs odor from the reduction of organic and inorganic sulfur compounds; and methane (CH_4), marsh gas or sewer gas, from the anaerobic decomposition of sewage solids. Methane is dangerous when mixed with atmospheric oxygen in confined spaces such as manholes and partially filled pipe lines. Evolution of H_2S and CH_4 may be effectively controlled by maintaining sewers free from roots and fungi. Bottom sediments also contribute to gas production and should be kept to a minimum.

The relation between adequate sewer maintenance and the prevention of foul odors due to dangerous gases; structural failures; and increased pollution-potential of sewage is not usually appreciated. Nevertheless, it can be scientifically and practically demonstrated that a clean,

well-maintained system may be practically innocent of these undesirable evils while serving the same population and carrying the same or even greater volumes of sewage.

Either pH and the methyl orange alkalinity or the oxidation reduction potential or both may be employed to survey and dictate the maintenance and cleaning program. For example, using city water as a base, the alkalinity of a sewage will disclose the condition of a pipeline or system, due to the fact that decomposition increases the alkalinity by increasing the basic compounds. For example, if a city water has 80 mg/L M.O.alk. and a street lateral sewage contains 500 mg/L, this sewer is undoubtedly badly obstructed. When cleaning work is instituted, the alkalinity of the sewage will decrease. When the alkalinity more nearly approaches the city water value, it may be safely assumed that the sewer is substantially free from obstruction. Controlled experiments have shown that O-R-potential likewise may be used to survey and operate a system. This value denotes biological classification or various levels of electrical potential in the liquid at which entirely different organisms operate. For example, if a high positive potential is maintained in a line, then regardless of the concentration of organic or mineral sulfates present, hydrogen sulfide will not be evolved and disintegration of structures will not occur. Prevention of hydrogen sulfide is of prime importance in the operation of sewer systems in the warmer regions such as our southern and western states.

Some years ago, new sewage treatment facilities at Flora, Ill., could not be brought into successful operation. Investigations revealed the cause to be decomposing solids in the sewers. When the lines had been flushed, the treatment problems at the sewage plant ceased to exist.

Millions of dollars invested in sewage treatment facilities are failing to produce treatment results thus contributing to stream pollution and to public health hazards caused by dirty sewers. In addition, atmospheric nuisance and litigation resulting from uncontrolled odors and attendant deterioration of structures are associated with the operation of treatment plants receiving septic inflow.

Reinforced concrete pipes should not be used for sewers where control of O-R-potential is not effected if failures are to be avoided.

Root Removal

The general practice is to employ mechanical means to cut and remove the offending roots after their presence has been disclosed by sewer stoppage. Due to the size of root stems and damage to vitrified pipe hubs, or bells, caused by lateral expansion during growth, it frequently is found necessary to dig up and relay the connection. This is a costly and messy procedure and cases on record show that this is no guarantee of freedom from further trouble.

As a last resort, many valuable trees have been cut down in order to maintain sewer service uninterrupted. One eastern city forester reported having "60,000 shade trees, 25 to 50 years old, growing along 500 miles of streets. The number of requests for tree removals as the result of sewer lateral stoppage is overwhelming, sometimes as many as ten a day. We have removed a large number of trees in order to relieve this condition, but it is a physical impossibility to comply with even a small percentage of requests, and we do not like to remove otherwise fine trees. However, when the plumbers' bills mount up, the citizens demand action."

Ridgewood Experiences

Many cities have revealed that the problem of root control was on an emergency basis.. Prior to 1936, Ridgewood, N. J., was no exception, obstruction of sewer mains and house connections being all too frequent occurrences.

Foul odor conditions prevailed the year around at the sewage treatment plant, and concomitant disintegration of concrete structures had progressed to the extent that some structure walls were "razor backed" and were rebuilt by the Gunite method. Chlorine demand and costs were high and very poor results were being obtained from the biological oxidation process.

Chemical precipitation was a feature of the 1936 reconstruction program. Major difficulties encountered in operating this treatment process prompted a thorough investigation which ultimately revealed that the tree roots were primarily responsible and should be brought under control.

Efforts to dislodge the extensive growth of fungus in the sewer system by the application of chlorine had proved uneconomical and unsuccessful. The use of copper sulfate was next considered, since it was known that copper sulfate (blue vitriol) is used extensively in water treatment for the control and elimination of taste and odor producing microscopic organisms and undesirable aquatic plant growths. Microscopic examinations showed *Beggiatoa* was the predominating species of fungus present in Ridgewood sewage. Hale[1] indicated that a minimum concentration of 5 ppm. was necessary for the eradication of this species.

About two pounds medium size crystals were sprinkled along the exposed pipe inverts of intersection and terminal manholes throughout the sewer system, this work being performed from the street level. Two barrels (total 800 lb) copper sulfate were thus applied to the system over a period of several days. Subsequent to this application some pipes were found literally full of the dislodged fungus growth being carried along in the flow. As a result of this preliminary treatment, odors were reduced to such extent that up-sewer chlorination was discontinued and the need for prechlorination at the plant for odor control was confined to a few summer months. Dislodged root masses were observed in the plant influent from time to time and stoppages in the sewer mains became less frequent.

The annual application of $CuSO_4$, to the system has been an established practice at Ridgewood, N. J., since 1937. A hand bill was prepared for distribution to residents, to pave the way for $CuSO_4$ work on the house connections from within the homes, since these pipes were found to be in worse condition than the mains in the streets.

Two or three pounds of crystals are applied through the commode and flushed outside the cellar soil pipe system. This program has been accelerated by the recent assignment of an employee to this work exclusively. Pre-chlorination for odor control is now unnecessary, even during summer months. Sewage is "fresher" and therefore more amenable to treatment by biological oxidation. This is reflected in improved effluent quality, despite increased population load on original trickling filter unit.

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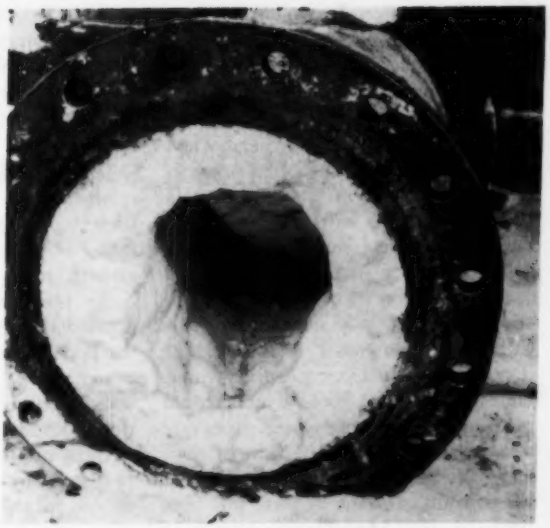

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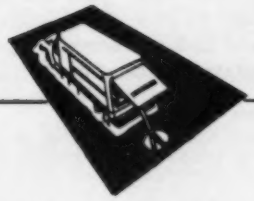

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House Connection Treatment

Several connections whose outlets were available for sampling were selected from a sewer map. They were located in sandy terrain and it was not unexpected that the owners, when approached for permission to experiment, told of repeated sewer trouble and plumber bills and readily granted the desired permission.

The property owner was informed of our intention to use copper sulfate and it was specially emphasized that $CuSO_4$ had no magic qualities; that it merely had a toxic property capable of killing live roots which would in time break loose or disintegrate and be swept out by the flow of sewage. It was also emphasized that these root growths within the pipe were of 10-, 15-, 20-year standing; that we had no way in which to ascertain the extent of their infiltration and the amount of copper sulfate which would be necessary to kill them.

Success crowned these efforts and a comparison of analyses made before and after the copper treatment showed that in all cases the pH-alkalinity equilibrium had declined. When subsequent determinations disclosed a calcium carbonate equilibrium more nearly resembling the city water, the connection was considered clear and no further treatment given.

A short street of seventeen homes having a bad record of sewer stoppage due to roots was next tackled. After several weeks the determination showed a decline in equilibrium from pH. 7.9 and alkalinity of 435 mg/L to pH 7.7 and alkalinity of 227 mg/L. It is important to state that before the copper sulfate treatment of house connections on this street, the sewage was not responsive to any dose of chemical coagulant, whereas afterwards it was found to be amenable to chemical clarification with much smaller doses of chemicals than had been previously tried.

When a year had elapsed from the completion of work on this street, each connection was gone over with sewer cleaning equipment. All connections were found clean and clear; no roots were brought out.

Dosage

Since the extent of the root growth in any given pipe is unknown, a greater or lesser amount of the crystals may be required to permeate the whole mass.

An individual root mass entering at one point may clog a pipe or connection just as effectively as half a dozen, but obviously more crystals would be necessary for the greater quantity of roots.

Property owners and occupants furnish "case histories" by relating their woes with their sanitary connections, and the extent of the root growth may be deduced therefrom.

As previously stated, crystals are applied through the commode within the home. The operator carries a container of crystals and puts two or three pounds through each connection. Where serious trouble and recurrent plumber visits have been experienced by the tenant, initial doses of six to ten pounds have been applied in an attempt to insure complete contact, and such cases have been marked down for repeat doses at weekly, for nightly or monthly intervals, as the conditions seem to dictate. After the initial high dose, and in the absence of any further clogging troubles, normal low doses of crystals may be used.

When a connection is completely plugged, rodding must be resorted to to restore flow through the root masses. Thereafter copper sulfate crystals may be applied, but not before. There has to be some flow through the connection in order to carry the solution down through the roots for the attack.

Street Sewer Mains

A light truck and a barrel of copper sulfate crystals are the operator's tools. Junction and terminal manholes are opened, a small scoopful of crystals are sprinkled along the invert of the pipe, and the manhole cover replaced. Thereafter the flow gradually dissolves the crystals and the resulting solution contacts roots and fungi as it flows down stream. About two pounds per manhole is applied, but here again this amount is increased as in the case of the house connections, when records indicate serious root trouble.

Under no circumstances should an amount of crystals sufficient to obstruct the flow be placed in the inverts, nor should crystals be placed in the traps of automatic siphon type flush tanks. In the first place, they will not dissolve, due to the absence of flowing water, and secondly, they may tend to corrode the metal.

It is recommended that periods of normal to low flow be chosen to introduce the copper sulfate. Both the time of contact and the concentration of the solution are thereby enhanced. A preventive dosage may be given annually following the initial treatment. Old roots do not return, but new root infiltrations may develop.

The total amount of copper sulfate used in any one day is not enough to adversely affect sewage treatment plant operations, particularly since the chemical dissolves slowly.

Careful records of all work should be kept so that not only will the results be disclosed, but also to indicate when all of the system and house connections have been serviced.

Important Don'ts

1. Don't put $CuSO_4$ crystals in fixture traps. Corrosion by interchange of metallic ions will occur and eventually eat holes in the traps. Flush the crystals through the commodes when applying from within homes, and follow with a sufficient amount of flushing water to insure (a) their transit through the soil pipe to beyond the cellar wall and (b) their conveyance to and against the root obstruction, where the crystals will dissolve, discharging the solution slowly into the root mass.
2. Don't expect black magic properties from $CuSO_4$. Remember that a good root mass is well-nigh impervious to concentrated sulfuric acid. Only the life is taken by copper sulfate treatment and thereafter the normal processes of decay must ensue.
3. Don't waste $CuSO_4$ in the system during periods of high flow. The dilution factor is too great and the resulting concentration of the solution too weak to be effective. Pick low-flow periods.
4. Don't expect $CuSO_4$ to clean sewers and house connections mechanically obstructed by breakage, bad connections, or defective bends.
5. Don't undertake to guess at the dosage of $CuSO_4$. The amount used on a system in any given time should be arrived at by collaboration with the plant superintendent, who is best able to determine what the traffic will stand, by close observation of the biological and/or chemical processes incorporated in the plant.

References

(1) Hale, Frank E., "The use of copper sulfate in Control of Microscopic Organisms."

Resistance of Sewer Pipe Jointing to Tree Roots

by C. E. KEEFER

Assistant Bureau Engineer of the Bureau of Sewers in Baltimore, Maryland

ONE OF THE vexing problems associated with the operation of sanitary sewers has been the entry of tree roots through the joints into sewers. In order to throw additional light on this problem tests were begun in 1948 at the Back River sewage-treatment works, which serves Baltimore, Md.; these facts have been continued since that time.

Three 6-in. terracotta pipe lines (Fig. 1) were laid in a horizontal position 18-in. below the surface of the ground. The center lines of these pipes were laid 3-ft. apart and were parallel with each other. Four parallel rows of Lombardy poplar trees, each row containing four trees, were planted between and adjacent to the three pipe lines. Each pipe row contained five joints. The joining materials used in one row was duplicated in the other two rows. The following was the kind of joints used:

1. Clay and salt joint.
2. Cement joint.
3. CPI-2 bitumastic compound.
4. Copper joint.
5. G-K primer and compound.
6. G-K compound.

How Joints Were Made

Each end of each of the 6-in. pipelines connected with 12-in. by 12-in. by 6-in. tee, set in a vertical position. The joints in the vertical pipes consisted of a mixture of clay and salt. This joining material was used, as it had reported that salt repelled tree roots.

The cement joints were made by first inserting and caulking a gasket of jute, soaked in Portland cement grout, into the joint. The remainder of the joint was then completely filled with cement mortar, which was carried about 2-in. beyond the outer face of the bell. The exposed surface of the joint was beveled off from the outer edge of the bell at an angle of about 45° with the barrel of the pipe.

The CPI-2 bitumastic compound, used to make the third group of joints, was furnished by the Wailes-Dove-Hermiston department of the Koppers Company. When making the joints with this material, dry jute was first inserted in the annular space and then the remainder of the joint was filled with the melted bitumastic material.

The copper joints were made by inserting dry jute in the bottom of the annular space. A crimped sheet copper ring, 3/4-in. wide, was then inserted in the joint.

Two types of joints, using G-K sewer joint compound as made by the Atlas Mineral Products Company, were used. One type consisted of painting the inside of the bell and a few inches of the outside of the adjoining spigot with G-K primer the day before the joint was poured; no primer was used in the other type of joint. Dry jute was inserted in the bottom of the annular space and then the G-K compound was poured into the joint.

The three rows of pipes were kept filled with water to attract root growth into the pipes.

Results of Tests

On August 24, 1956, eight years after the pipes were laid, an examination of their interiors was made. Of the six joints made of clay and salt three were completely filled with roots, two had one small root each and one was free of roots. Two of the joints made of CPI-2 bitumastic compound were free of roots, but the other one contained one small root. There were no roots in any of the cement joints, copper joints, G-K compound joints and joints made of G-K compound that had been previously primed with G-K primer.

Conclusions

The tests indicate that joints made of a mixture of clay and rock salt do not prevent the entry of tree roots. This type of joint therefore, is not recommended. The tests with CPI-2 bitumastic compound were not entirely successful, since one of the three joints failed to prevent the entry of roots. Further tests will be made with this material for the purpose of reaching more definite conclusions. As all of the other joint material prevented the entry of roots into the pipe line, the results indicate that their use is warrented in locations where tree roots are present.

It should be pointed out that all of the joints were carefully made, and unless high-grade workmanship is employed, unsatisfactory results may follow.

Since the tests described were begun, additional pipe joining materials have been perfected and are in use. It is planned to widen the scope of the investigation by testing some of these newer materials.

The Bureau of Sewers is under the general direction of George A. Carter, Director of Public Works, and John J. Hunt, Sewerage Engineer. Dr. Abel Wolman is consultant to the Department of Public Works.

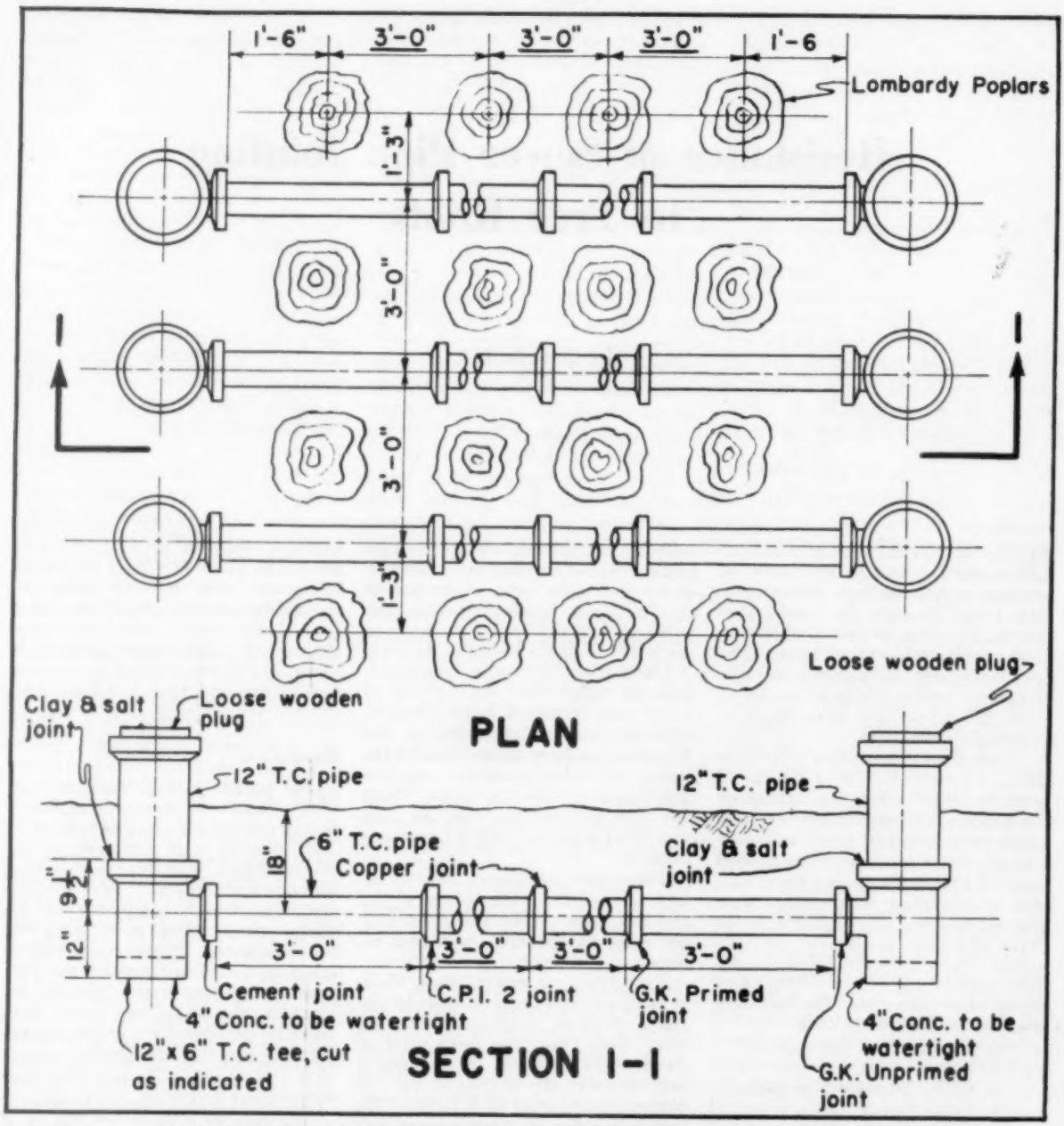

Fig. 1—LAYOUT of 6-in. terra cotta sewer pipes provides with different types of joints.

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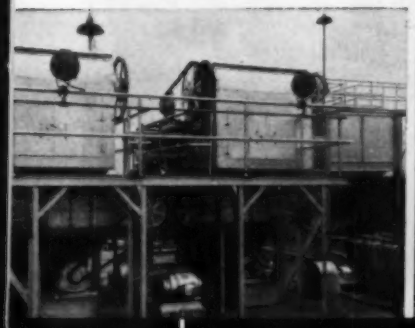
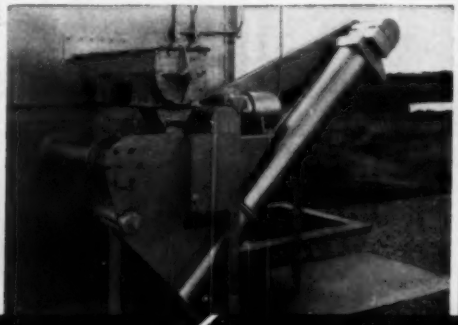
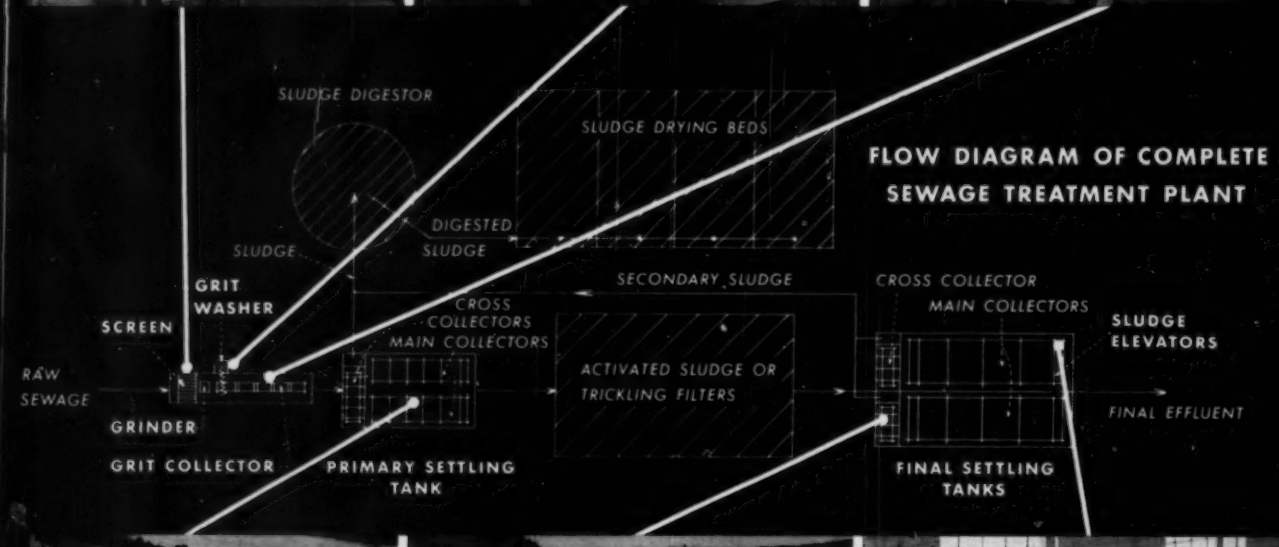
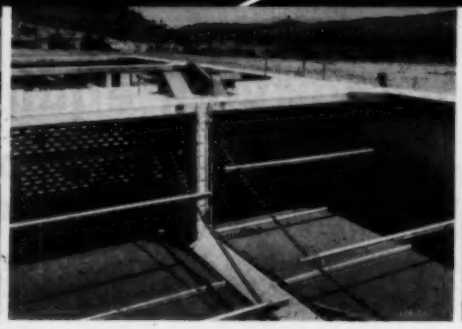
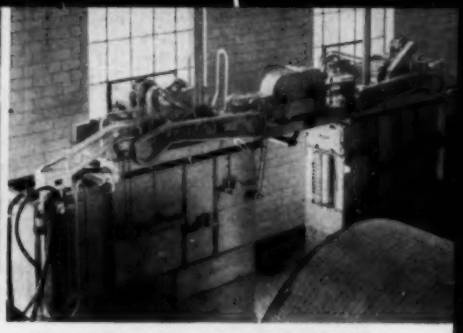






FLOW DIAGRAM OF COMPLETE SEWAGE TREATMENT PLANT





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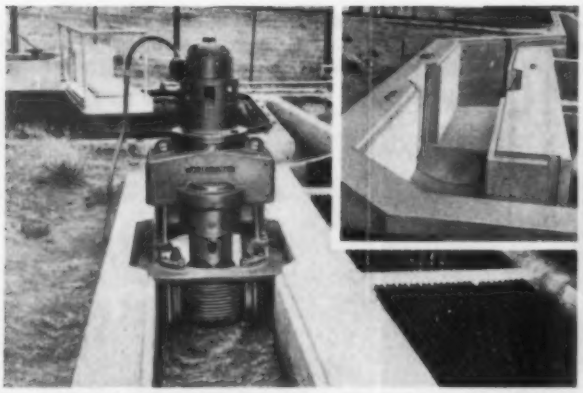
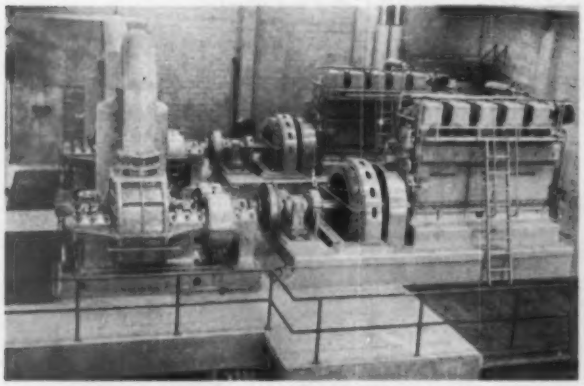
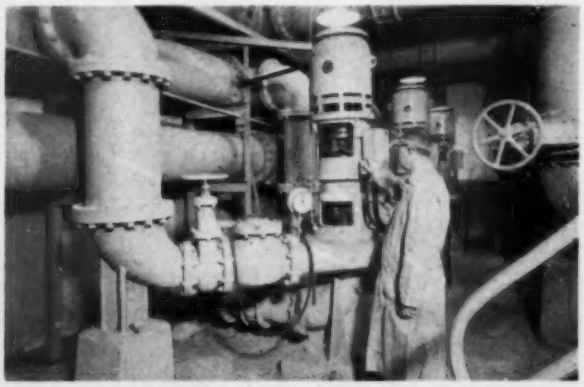


COMMINUTORS. Since raw sewage flows straight through in the Worthington design, the comminutor can be installed in a simple rectangular channel (inset) without expensive masonry work. This one is located at Klamath Falls, Ore.

MIXFLO PUMPS. Available in sizes from 2 MGD to over 300 MGD, Mixflo pumps have non-clogging sewage-type impellers for passing large solids. This one handles raw sewage in the new Salem, Ore., Treatment Plant.



DUAL-FUEL ENGINES. Operating on oil or gas or any combination of both, these Worthington dual-fuel engines drive blowers for the Little Ferry, N. J., Treatment Plant of Bergen County Sewer Authority.



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Primary Sedimentation

by DON E. BLOODGOOD

Professor of Sanitary Engineering, Purdue Univ., Lafayette, Ind.

OPERATION of primary sedimentation tanks is an important part of the operation of any sewage treatment plant. Therefore, it should be seriously supervised in order to obtain the best removals possible.

It is necessary to understand some of the principles of sedimentation so that operation procedures are always such that they do not interfere with the natural tendencies of sediment. The biological and chemical processes are affected by certain laws of bacteriology and chemistry; sedimentation is influenced by the laws of physics. In the biological and chemical processes there are ways of changing environment so that there are modifications of the degree of effectiveness and the rate of accomplishment. In treatment of sewage by sedimentation there are not feasible ways of modifying the process to improve it.

Factors Influencing Sedimentation

The basic factors that influence the rate of sedimentation are (a) the size of the particle, (b) the specific gravity of the particle, and (c) the viscosity of the liquid. The larger the particle the faster it will settle in a liquid, providing it has a specific gravity greater than one. The greater the specific gravity the faster a particle will settle. The viscosity of the liquid has an effect on the rate of particles settling in it.

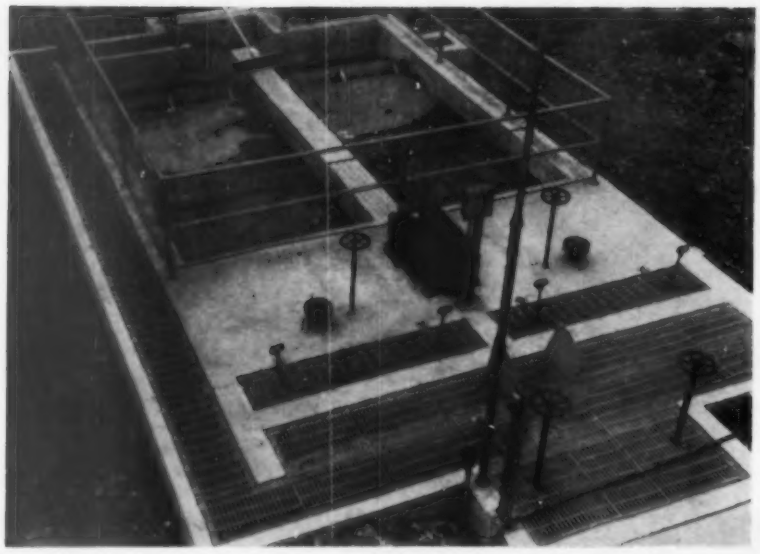
If larger particles settle faster, it would be advantageous to bring small particles together to form larger masses. This is sometimes done prior to settling by agitation with air or by mechanical stirring to bring the small particles in contact with each other. Some solid particles cling to each other once they make contact. The coagulation of particles is not accomplished in primary settling tanks. Severe agitation, such as turbulence caused by pumping, could be detrimental in settling because some of the solids might be broken into smaller pieces.

Specific gravity is the ratio obtained by dividing the weight of substance by the weight of an equal volume of water. The higher the specific gravity the more easily will the material settle when placed in water. Some substances that have a very low specific gravity may float when first placed in water, but after they have absorbed water they become nearly the same weight as water and may, after suspension in water for a long time, have a tendency to settle when left in a quiescent state for a period of time.

The specific gravity of primary sludge has been determined and it is reported to be just a little greater than one. This indicates that many of the solids in primary sludge when wet have a weight not much greater than water. Some of the solids, like grit, have a specific gravity of about 2.5. Attempts have been made to add powdered high specific gravity materials to sewage in the hope that the heavier particles would become attached to the lighter ones, weighting them sufficiently so that they would settle in a reasonable period of time.

The suspended solids in sewage do not all settle out in a reasonable period of time. In fact, only about 62 per cent can be removed by sedimentation. This means that the particles are so

PRIMARY SETTLING tanks with drive for sludge collector and skimming mechanism at inlet end (foreground)



TWIN primary tanks at Indiana State Soldiers Home are partially decked for accommodation of operating controls and machinery, as well as to help relieve surface disturbances due to wind. Tank by-pass is under grating at left

small that they do not move through the water or that their specific gravity is very close to one.

The viscosity of the liquid in which solids are suspended has a definite bearing on the rate of solids settling. Some liquids, such as syrup, are very viscous and materials move through them with great difficulty. The viscosity of many liquids can be decreased by heating them. The water in sewage behaves the same way, although the change in viscosity is not very great in the ranges of temperature usually experienced.

This natural change in viscosity between winter and summer would be such as to make it seem that the lower viscosity water would be experienced in the summer and that consequently, solids in sewage should settle more readily in the warmer weather than they do when it is cold. The effect on per cent removals due to viscosity changes is not apparent in data collected at sewage plants.

These several factors influence the rate of settling. The resistance or particles to settle was first expressed as a "law for drag" by Sir Isaac Newton. The law has been expressed in various ways, but the one that expresses the velocity of settling of spheres will suffice to show the relationship of the several factors. In the Stokes Law equation

$$v = \frac{1}{18} \frac{g}{\mu} (p_1 - p) D^2 \quad \ldots\ldots (1)$$

in which

v = the velocity of settling;
g = the gravity constant;
μ = the kinematic viscosity;
p = the mass density of the fluid;
p_1 = the mass density of the spheres;
$\frac{p_1}{p}$ = specific gravity; and
D = the diameter of the spheres.

Besides the natural laws that govern the settling of solids in liquids there are many other factors that have a bearing on the degree of removal obtained in a settling tank.

One of the most important of these last-mentioned factors is that of rate of flow through the settling tank. Hazen[1] in 1904 developed a theory for per cent removal in an "ideal settling tank." He expressed this theory in an equation showing the factors that he believed to be important. The formula is:

$$\text{Per cent removal} = \frac{a}{t} = \frac{V_s}{Q/A_H} \quad \ldots\ldots (2)$$

in which

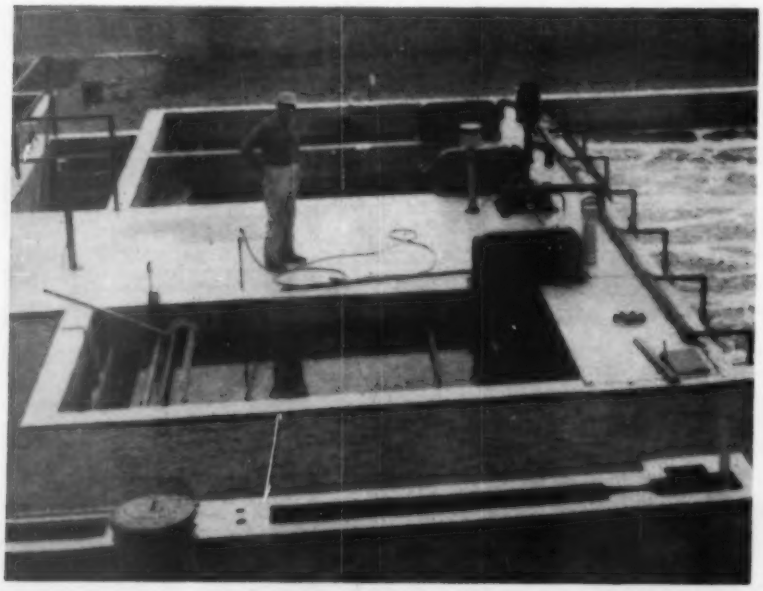
a = detention time;
t = time for particle to descend through a depth, D;
V_s = settling velocity;
Q = discharge; and
A_H = surface area of the tank.

The equation does not have an expression for the depth of the tank. Therefore, if the relationships are taken to be valid for an ideal tank the depth of a settling tank must not be of importance. According to the theory, a settling tank could be infinitely shallow. It seems unlikely that any such unrealistic tank will ever be constructed. Control agencies have not as yet allowed settling tanks to be constructed that were not at least 7 feet deep.

Other Factors Involved

There must be still other factors, therefore, that influence the per cent removal of solids in a tank.

It has been stated that inlet velocity, effluent velocity, turbulence in the tank, density currents, and bed scour are also partially responsible for the degree of clarification obtained in settling tanks.



SMALL Indiana plant has three primary settling tanks to accommodate wide range of flows ahead of activated sludge treatment. Note small collector travel and rotary skimmer (left)

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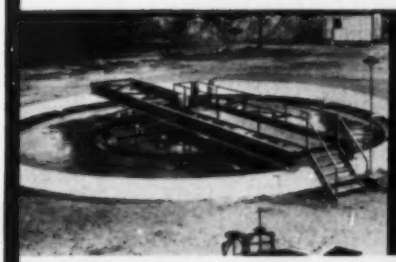

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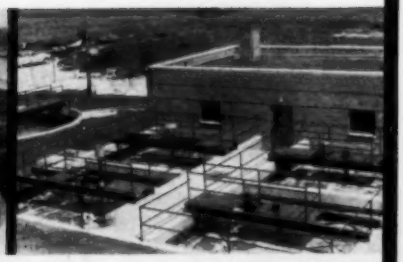

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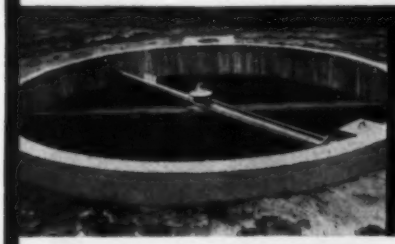

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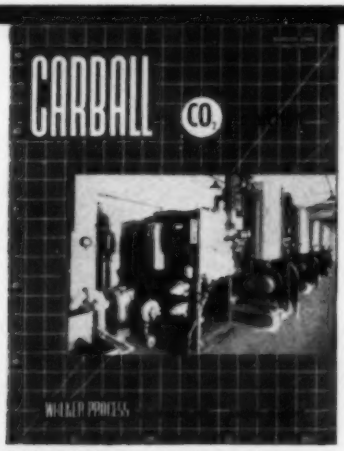

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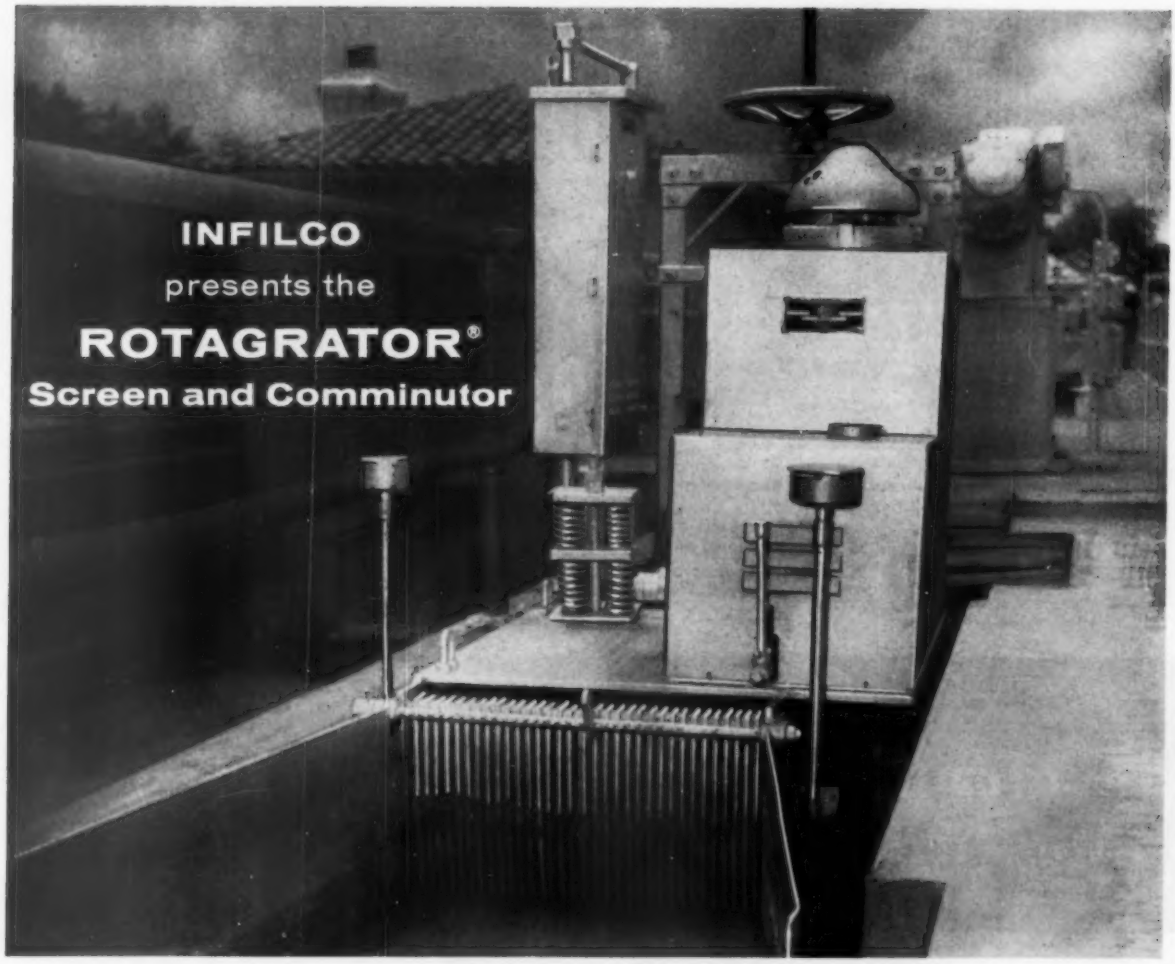

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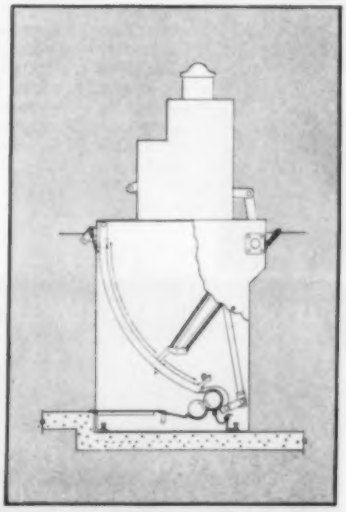
Most materials are handled in a single pass. Rollers at the bottom of a curved bar screen intercept heavy solids—lighter ones are raked down automatically. Any over-size comminuted solids are automatically rescreened and returned to the comminuting rollers until reduced to a size that permits passage through the screen.

No matter what the load may be, the unit operates continuously without harm to the mechanism, because of its rugged construction and safety devices incorporated in its design.



The "ROTAGRATOR" screen and comminutor is a completely packaged unit ready for simple and easy installation. A full range of sizes is available. For complete information write today for Bulletin 5150-A.

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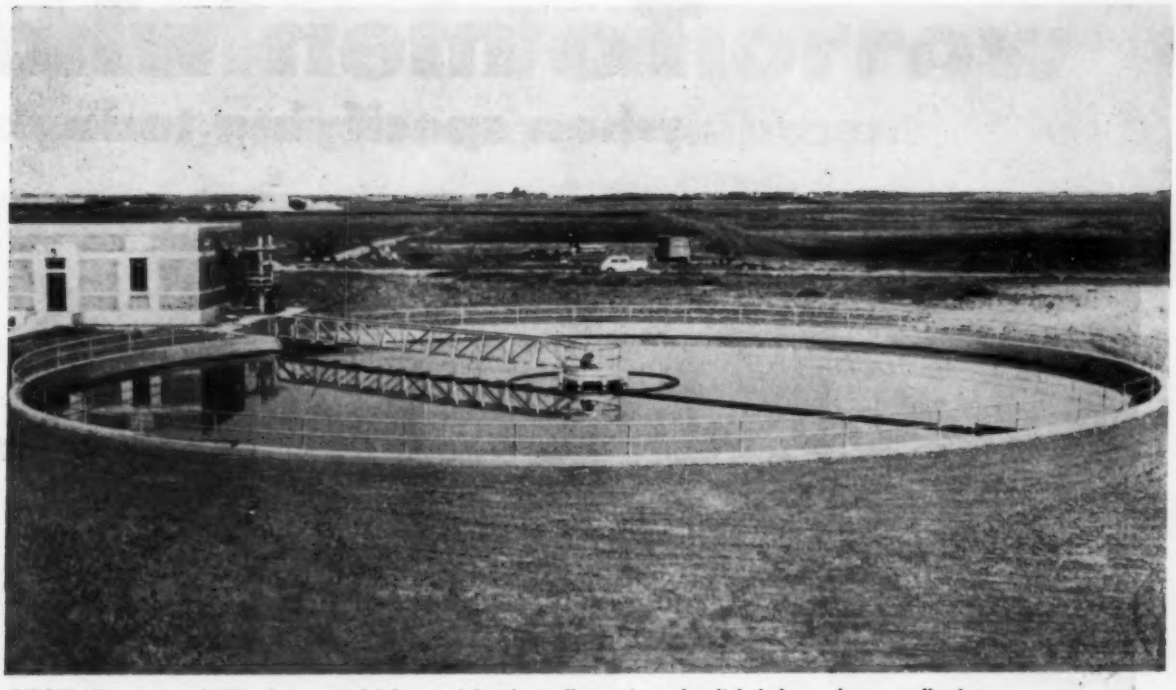


CIRCULAR primary clarifier has central inlet, peripheral overflow weir, and radial sludge and scum collection

When sewage enters a settling tank there is usually a disturbance at the point of entry. This can be expected, inasmuch as the influent port or ports are smaller than the cross-sectional area of the settling tank and the velocity at the port of entry is greater than the velocity through the tank. This high velocity has been noted and efforts have been made to quiet the disturbance at the inlet. A great many methods of admitting sewage to settling tanks have been tried, but even after many years of experience in the use of the different ports no one has the one best way.

The higher the velocity of the entering sewage, the more energy or force is placed on the supposed to be quiet sewage in the tank. If there is a large volume of water in the tank the force of the influent does not cause much turbulence in the tank. However, if the force is large, considerable turbulence can be expected in a settling tank.

Much effort has been expended on the development of baffles at the influent end of the tank. The hope has always been that baffles could be devised that would prevent turbulence in the tank. Probably more attention has been given to the quieting of turbulence than to the elimination of high velocities of the entering stream.

These statements are not made to imply that baffles are not helpful in quieting turbulence in settling tanks. It is believed, however, that if there appears to be considerable turbulence in a settling tank it is a good plan to observe whether the entrance port is being unduly constricted by a weir, gate, or some other control device that could be so modified as to reduce the entering velocity.

Density currents are said to cause difficulty in settling tanks. They can be the cause of some reduction in the per cent removal of solids obtained in primary sedimentation tanks. Density currents may be the result of variations in temperature in various parts of the tank or changes in temperature in the sewage while it is in the tank. The density currents may result from movements of sewages, in the same tank, that have different solids concentrations.

Density currents probably exist to some extent in all primary settling tanks, but it seems that they are probably very minor compared with the turbulence caused by the entering sewage. Perhaps, in time, a settling tank can be designed that will eliminate all turbulence caused by the entering sewage. When that has been accomplished attention can and should then be directed to elimination of turbulence caused by density currents.

If the effluent is removed at one central point there are apt to be velocities that will disturb the particles that are settling according to the sedimentation laws. The primary settling tanks designed for modern sewage treatment plants have systems of effluent weirs such that the effluent is collected from a fairly large portion of the tank surface.

Of course, when too large a portion of the surface is devoted to effluent troughs there may not be adequate area for scum collection and removal. In most situations it is probably desirable to have as much effluent collection weir length as possible.

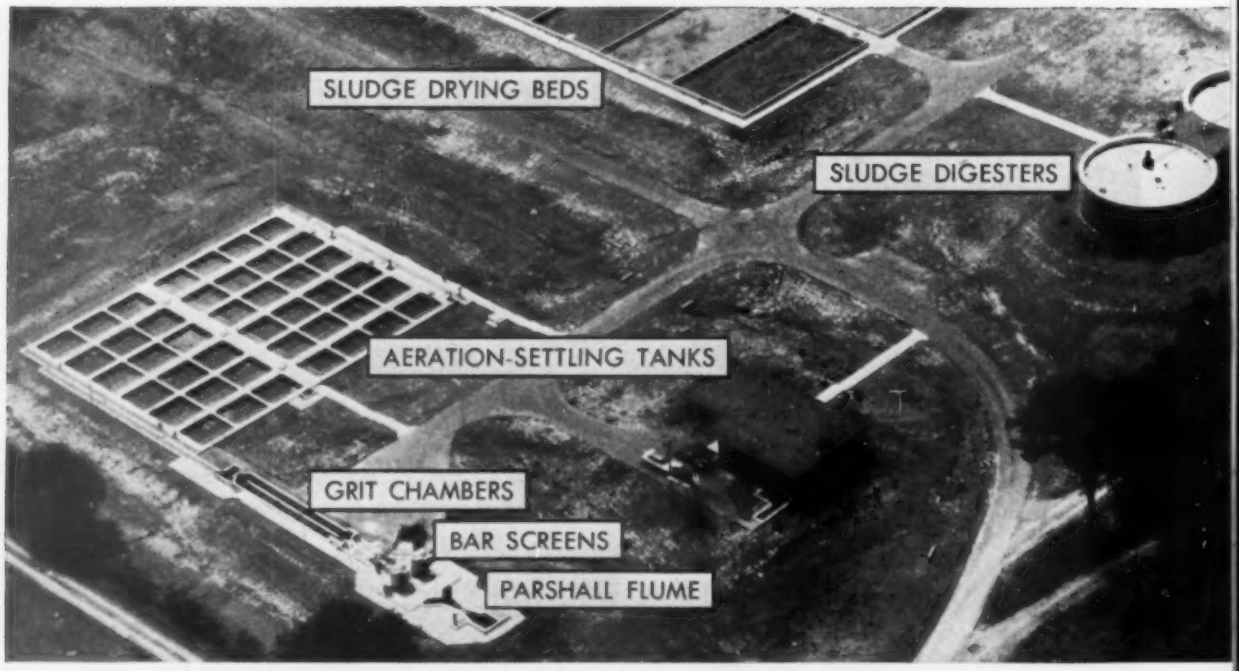
Considerable has been written about the disturbance of settled solids after they have been deposited on the bottom of the tank. "Bed-scour" is the term used to describe the movement of settled solids. It is not likely that deposited solids will be moved from the bottom of the tank by the velocity of flow through the tank. These solids may be disturbed by the turbulence of influent and effluent.

The sludge removal mechanisms may, when operated, move the deposited sludge at such a rate as to put it into suspension again. In most cases the sludge collection mechanism speed has been established by the experienced equipment manufacturer. If there appears to be any sludge disturbance it would be well to check the mechanism speed and determine whether it is greater than 1 foot per minute.

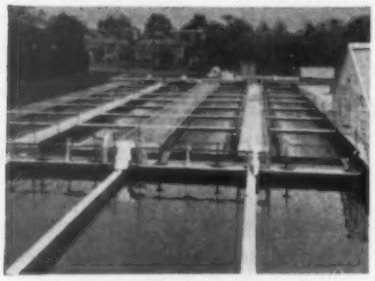
Camp[2] has said: "In the simple theory of sedimentation of discrete particles in an ideal basin it is demonstrated that the removal is a function of the overflow rate and is independent of the tank depth and the

R-272

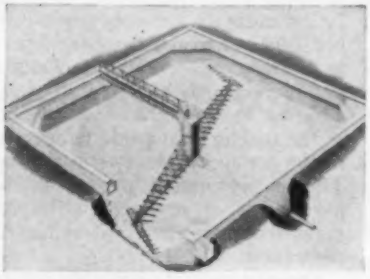
To men who
when specifying today's



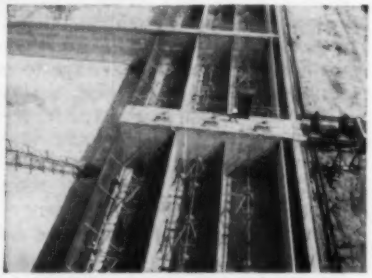
PRIMARY SEWAGE TREATMENT PLANT serves a city of 19,000 yet was designed to accommodate expansion for the next 25 years. It incorporates Link-Belt Thru-Clean mechanically-cleaned bar screens; Straightline Type S grit collectors with washing and dewatering screws; Straightline longitudinal and cross sludge collectors.



STRAIGHTLINE COLLECTORS for rectangular settling tank feature peak-cap bearings, pivoted flights and Straightline action for top efficiency.

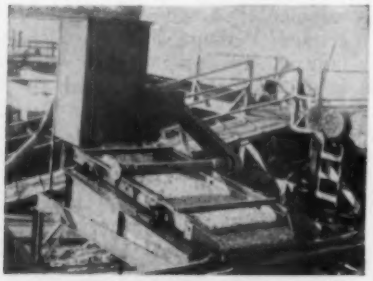


CIRCULINE COLLECTORS — Four types for square or round tanks provide positive sludge and scum removal in shortest time without septicity.



STRAIGHTLINE SLOW MIXERS for rectangular tanks, cross or transverse horizontal flow. Degree of mixing can be varied to produce maximum size floc.

FLASH MIXERS thoroughly mix chemicals prior to flocculation . . . prepare chemicals and water for immediate flocculation.



LIQUID VIBRATING SCREENS are widely used for thorough removal of fine solids from industrial liquids. Several sizes with fine screen cloths.

BIO-FILTRATION SYSTEMS use high-rate shallow filters . . . recirculation of effluent from filter to primary settling tanks, from final tank to filter.

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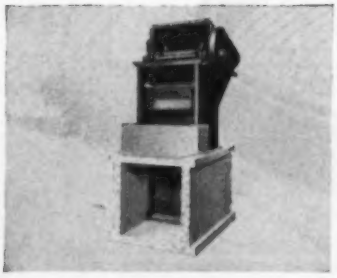

THRU-CLEAN BAR SCREENS remove large floating particles from large volumes of water, protecting other equipment from damage.

TRITOR SCREENS remove both grit and screenings with one mechanism. Saves the cost of separate units to remove large solids and detritus.

LINK-BELT offers a complete equipment line assuring dependability for future demands

In supplying your needs in municipal sewage and water treatment or industrial waste treatment, Link-Belt offers three vital "extras" you won't find written into specifications or quotations. The first—durability—has been proved by exceptional service records. Second is the extensive Link-Belt equipment line—your assurance of impartial recommendations directly determined by your requirements and permitting expansion of capacity with minimum changeover. Third: prompt service, available from 40 Link-Belt district offices.

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OTHER LINK-BELT PRODUCTS INCLUDE: Rotary drum and revolving disc screens, scum breakers, air diffuser units, non-clogging spray nozzles, traveling water intake screens, Roto-Louvre sludge dryers, chemical handling machinery, car spotters and haulage systems, sludge bed cleaners.

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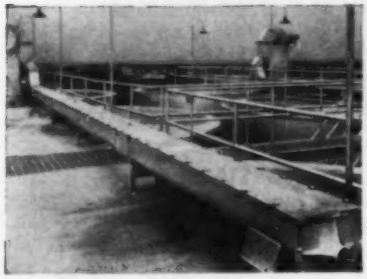
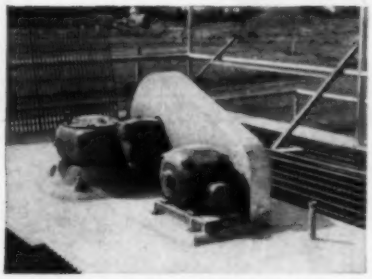
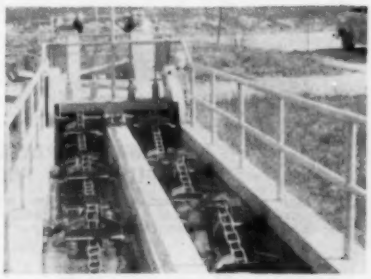


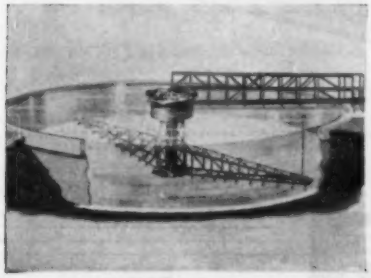
CONVEYORS AND ELEVATORS—a complete range for handling bulk or packaged chemicals. Screw conveyors and bucket elevators are shown.



POWER TRANSMISSION PRODUCTS include speed reducers; fluid and variable speed drives; bearings; chain drives as used on this Straightline mixer.

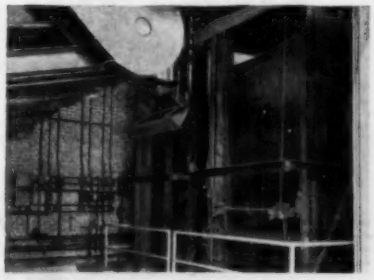


GRIT COLLECTORS AND WASHERS effectively collect and wash settled grit and separate it from putrescible organic matter before removing.



THICKENERS AND CLARIFIERS are made in several types and sizes, including rake and flight types, for high efficiency and low cost operation.

BELT CONVEYORS are supplied by Link-Belt for handling bulk or bagged chemicals, sludge filter cake or sludge from drying beds.

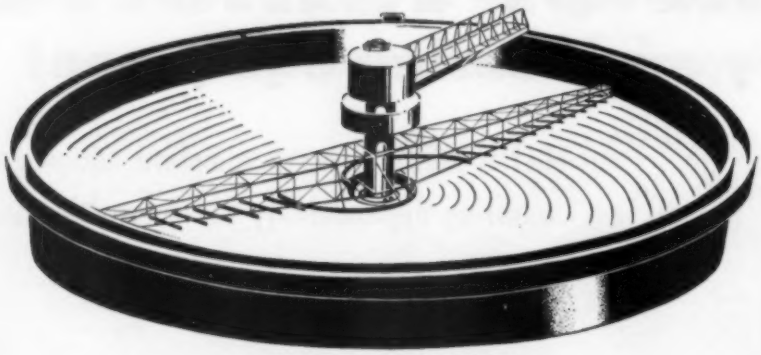


STRAIGHTLINE BAR SCREENS can't jam, assure constant, automatic screenings removal under extreme conditions. No moving parts under water.

For details circle 577 on inquiry card

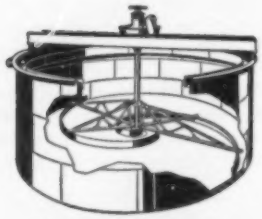
R-274

HARDINGE SANITATION EQUIPMENT



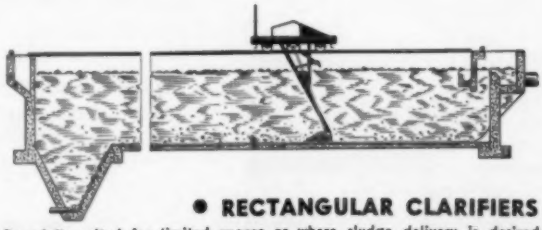
• CIRCULAR CLARIFIERS

Hardinge Circular Clarifiers are available in sizes up to 200' diameter, either center-column or beam supported for steel, concrete, wood or tile tanks. Sludge scrapers remove settled solids rapidly through central underflow discharge. Bulletin 35-D-15.



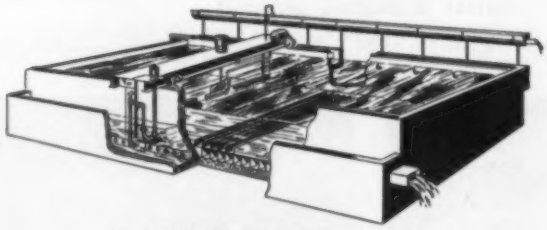
• THICKENERS

For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage Bulletin 31-E-15.



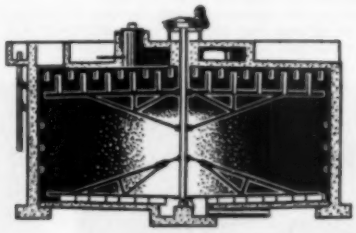
• RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. A traveling scraper and skimmer carriage removes settled solids from the tank bottom and scum from the top Bulletin 35-D-15.



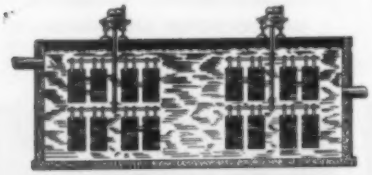
• AUTOMATIC BACKWASH RAPID SAND FILTERS

For high removal of non-settling or slow settling suspended matter. Self-cleaning sand bed. No shut-down necessary for backwashing. Traveling backwash mechanism. Bulletin 46-A-15.



• DIGESTERS

Sludge scrapers and scum breaker arms prevent scum accumulation, insure uniform gas production. Emit a dense digested sludge. Bulletin 35-D-15.



• FLOCCULATING UNITS

Slowly rotating paddles on vertical shafts bring the small flocs into contact to form larger masses and hasten precipitation. Bulletin 35-D-15.

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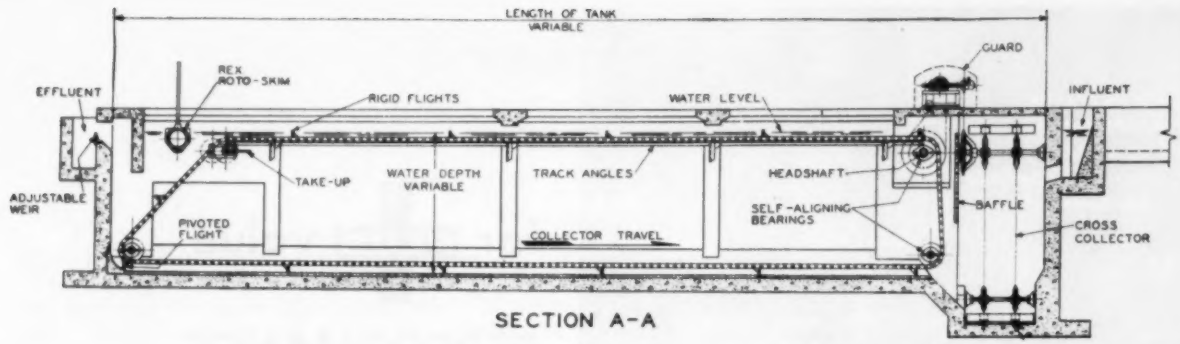
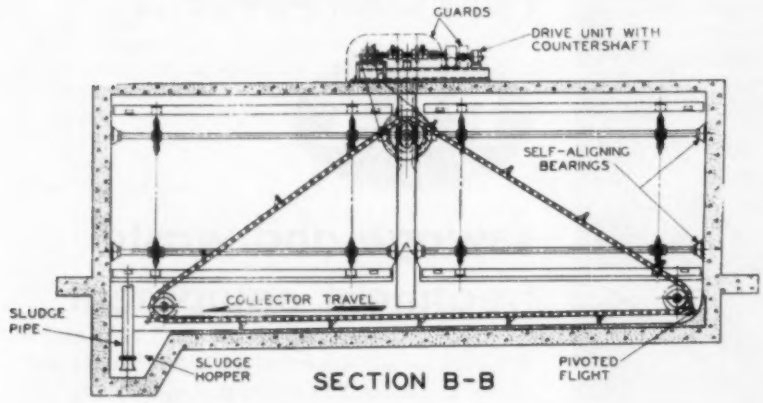
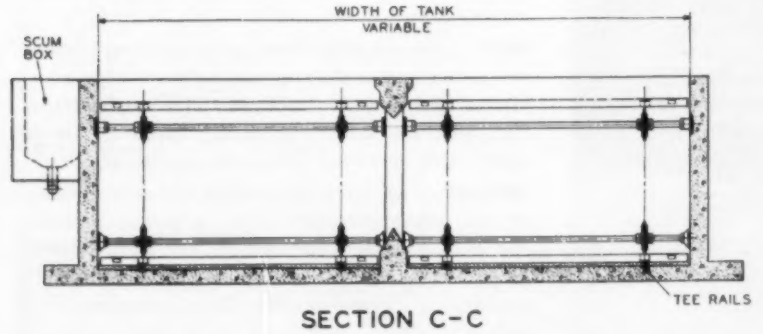


SECTION A-A



SECTION B-B



SECTION C-C

TYPICAL arrangement of mechanism in double primary settling tank

detention time. It follows from the simple theory that the most economical tank will have the least possible depth for the required overflow rate. For a given overflow rate and fixed horizontal dimensions the tank velocity varies inversely as the depth. Hence, the least possible depth is fixed by the maximum velocity that can be used without excessive scour."

It seems that he assumes that there will be time for sedimentation and that the scour lifts the sediment after it has been deposited. In reality, it may be that the sedimentation has never taken place because of the turbulence in the tank. After a number of years of discussion about the rating of settling tanks by the overflow rate method, there are now several design standards that call for the rating of tanks in this way. There are still some designers who hold to the "hours of retention" in a tank as a basis for determining the work load.

The gallons-per-square-foot rating is obtained by dividing the daily flow of sewage by the area of the tank. The removals that can be obtained at various overflow rates are given in Table 1.

It is apparent that settling tanks operating at a loading of 600 gallons per square foot per day should remove about 64 per cent of the suspended solids and that tanks loaded at considerably less than this rate will not have a removal rate much greater than that expected at the 600-gallons-per-square-foot-per-day rate.

Comments have been made about the points of collection of effluent, but no statement has been made relative to the overflow rate per foot of weir. Statements have been made in the various standards of design that the overflow rate per lineal foot of weir should be between 10,000 and 15,000 gallons per foot per day. It is known that tanks operating at this rate remove the expected percentage of suspended solids. It is also observed that these are the overflow rates attained in round tanks with circumferential weirs when loaded near the 600 gallon per square foot per day surface loading rate.

It seems doubtful whether it would be possible to get weir loadings that were too low, but certainly the weirs should not be placed so closely together that the velocity of flow up between the weir troughs was greater than the settling velocity.

TABLE 1
Overflow vs. Suspended Solids Removal

Overflow Rate, gpd/sq ft	Suspended Solids Removal, %
400	68
600	66
600	64
700	63
800	61.5
900	60
1,000	58.5
1,200	56.0
1,400	54.0
1,600	52
1,800	50

Both round and rectangular tanks are used for primary sedimentation. Individual operators usually have a preference for a particular shape. Either type should have mechanical sludge and scum collectors.

References

1. Hazen, A., "On Sedimentation," Transactions Amer. Soc. Civil Engrs., Vol. *58*, p. 63 (Dec. 1904).
2. Camp, T. R., "Sedimentation in the Design of Settling Tanks." Paper No. 2285. Transactions Amer. Soc. Civil Engrs., Vol. *111*, p. 895 (1946).

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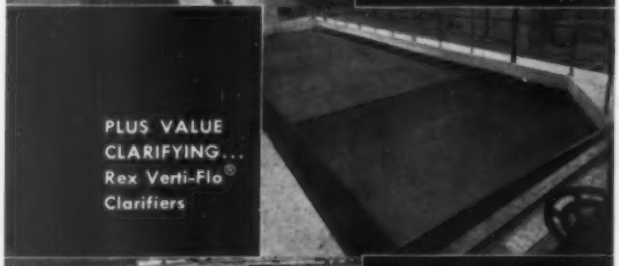

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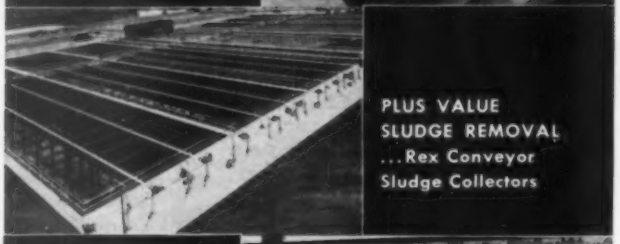

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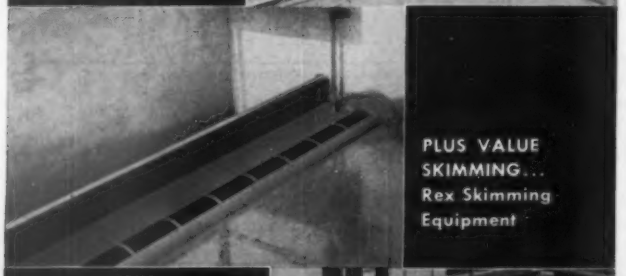

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Sewage Lagoons

by THEODORE JAFFE

Professor of Civil Engineering, Alabama Polytechnic Institute, Auburn, Ala.

IN RECENT YEARS many articles have appeared in various journals reporting the use of lagoons, or oxidation ponds, for sewage and industrial waste treatment. The manner in which these lagoons are used varies; sometimes it is the sole method of treatment, at other times it is an auxiliary method. What then is a lagoon, how does it work, and where can it be used?

What a Lagoon Is

A lagoon is a shallow basin in which the sewage or industrial waste is held for a period of time such that some desired degree of stabilization occurs. There may or may not be an effluent from a lagoon. Some are so designed that evaporation and percolation proceed at a rate sufficient to keep all the waste within the lagoon; others are designed for continuous effluent flow. Lagoons have banked edges of sufficient thickness to contain the waste waters. These banks have an inside slope of about 4 to 1, to reduce the erosion effects of any wave action due to winds. The entire area within the lagoon is usually stripped of vegetation, and the top and outer sides of the retaining banks are grassed.

Lagoons may be constructed so that the waste waters are from 3 to 5 feet deep, with an additional 3 feet of freeboard provided. The detention time in the lagoon varies according to the waste, the amount of pretreatment, and the removals desired. It may range from less than 1 day to 120 days. It is recommended[13] "that the sewage should be discharged into the center of the lagoon slightly above bottom elevation." B.O.D. loadings will be discussed after a brief description of how these lagoons achieve waste water stabilization.

How Lagoons Work

In oxidation ponds, treatment is accomplished by nature with very little assistance from man. If sufficient time and sunshine are provided bacteria and algae, with the help of occasional wind action, stabilize the organic matter in the waste water. (Fig. 1). Where the velocity of flow is reduced on entering the lagoon, suspended and settleable solids will be deposited. These plus the dissolved organic matter are the foodstuffs for the forces of nature.

Oxygen is supplied on the surface and stirred in by wind action. Additional oxygen is made available

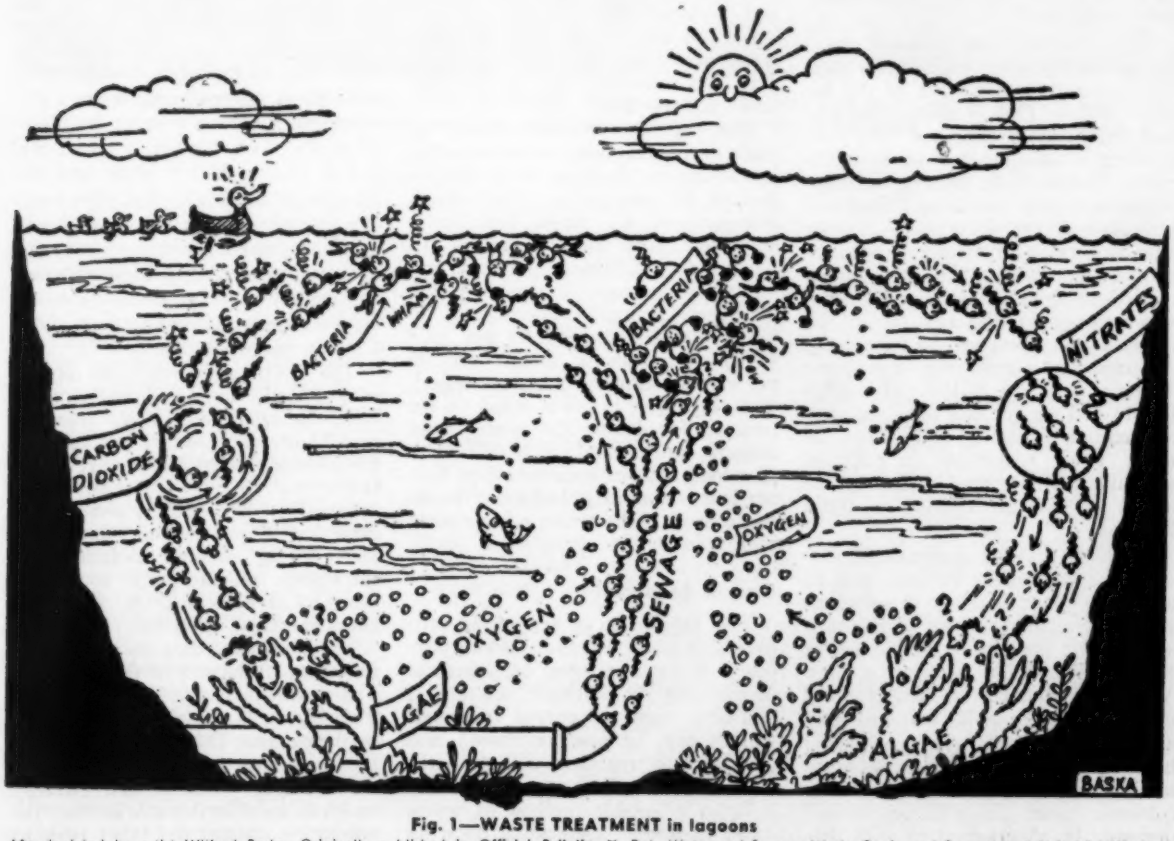

Fig. 1—WASTE TREATMENT in lagoons

(As depicted by artist Wilfred Baska. Originally published in **Official Bulletin**, N. Dak. Water and Sewage Works Conf., and **Sewage and Industrial Wastes**, Vol. 26, p. 239; 1954. Reprinted by permission)

by green plants; hence, the need for shallow lagoons so that these plants may receive the sunlight they require. Bacterial decomposition of the deposited or dissolved solids furnishes carbon dioxide.

Other nutrients, such as nitrogen and phosphorus, are also available from the sewage.

If any of these foodstuffs is not present (as may be the case with industrial wastes) it must be supplied by man; if toxic materials are present they must be removed before entering the lagoon.

Several other factors should be considered in the lagooning of liquid wastes. Due to the wide shallow area exposed to the atmosphere, evaporation of water will take place. Further, some percolation of water into the ground will also occur. Both of these tend to reduce the volume of waste to be disposed. Consequently, the use of lagoons is most efficient where these two factors are high. In North Dakota average evaporation rates amount to 1,340 gpad (18 inches per year). With percolation rates of ¼ to ⅛ inches per day, the total water loss from the lagoon will vary from 4,773 to 408,206 gpad[14]. At Victoria, Texas, it is estimated[4] that an average evaporation rate of 16 inches per year is obtained.

Some readers may wonder about the possibility of ground water contamination by percolation of the lagoon waters. This is always possible and should be investigated before lagooning is adopted for waste treatment. However, in passing through a lagoon a certain amount of bacterial reduction occurs. In a study of sewage lagoons in Australia it was reported[8] that a reduction of coliform organisms from 800,000 per ml in the raw sewage to 350 per ml in the effluent was obtained. Warrington[17] reported that a reduction of coliform bacteria from an M.P.N. of 1,100,000 to 450 per ml was obtained with a detention period of better than 30 days. These reductions in coliform organisms are primarily due to the action of natural enemies on these bacteria.

Lagoons may be designed to discharge a continuous effluent just as a sewage plant does, or if sufficient area is available, to rely upon evaporation and percolation to the extent that no effluent or discharge occurs. When an effluent is discharged it will usually be lower in B.O.D. and sewage solids; high in organic nitrogen; have considerable phosphorus, potassium, sodium; and have a lower coliform count. In addition it will probably be supersaturated with dissolved oxygen.

This state of supersaturation is due to the action of algae in the oxidation ponds. Algae are simple, one-celled green (or blue-green) plants that live in streams. They and the bacteria do the major part of the work in lagoons. This working as a team and living together is called symbiosis. The bacteria in the lagoons break down the organic carbon materials in the sewage to carbon dioxide. The algae take this carbon dioxide, and other nutrients, into their systems and give off oxygen. To perform their jobs, the algae need sunshine. In the presence of sunlight more oxygen can be produced by the algae than can normally be held in the water. As a result of this extra "oxygen pressure" the water becomes supersaturated with oxygen. Because it is always desirable to produce a plant effluent containing as much dissolved oxygen as possible, lagoon effluents are highly desirable on this score.

It should be noted that the effluent from an oxidation pond may actually contain more organic matter than the sewage entering. This increase will be due to the algae cells previously discussed and will be an asset to a stream rather than a liability, as would the sewage. The sewage organic material is highly putrescible and contains harmful microorganisms. The algae cells are neither putrescible nor harmful. Actually, they may be a source of food for fish and other aquatic life.

One further remark should be made on the reactions occurring within the lagoon. Because the stabilization of the sewage is a biochemical phenomenon, its rate of reaction is dependent upon the temperature. In winter, the efficiency (and the removal) decreases; in summer the efficiency increases. Tests run in North Dakota showed 65 per cent B.O.D. removals in winter and 95 per cent in summer on raw sewage[1]. This, however, is not a defect of the process, for during the winter most streams run full and can handle more of a load than in summer when they are low or even dry. Lagoon effluents fit in well with nature's scheme of things.

Uses of Lagoons

The lagooning of sewage is conducted in many ways for various purposes. It has been used on industrial wastes and on domestic sewage. It has been used for partial treatment (either pre- or post-treatment) and for complete treatment with or without an effluent discharge. Apparently it is an adaptable method of waste water treatment. Depending upon its use, the design bases will vary.

For normal domestic sewages without industrial wastes, a liquid depth of 3 to 5 feet with about 3 feet of additional freeboard seems to be standard. Detention times in the lagoon vary from a low of 15 days up to 120 days. Loading parameters found in the literature are of four types:

1. B.O.D. applied; for example 45 lb of 5-day 20°C. B.O.D. per acre per day[3].
2. Area-population; for example, 10 acres of lagoon per 1,000 population[15].
3. Capacity-population; for example, 200 times the daily sewage flow[15].
4. B.O.D. removed; for example 65 lb of B.O.D. removed per acre per day[9].

The parameters dealing with B.O.D. (items 1 and 4) are used where an effluent of a desired quality is to be produced. Where no effluent is to be produced, parameters 2 or 3 have been used. These four bases are for lagoons designed to furnish complete treatment for a sewage. Where the objective of the oxidation pond is not complete treatment, other criteria are used.

One use to which lagoons may be put is that of a finishing unit for plants that are overloaded or where a high quality effluent is desired. The University of Florida's sewage treatment plant utilizes a lagoon as a finishing or polishing unit for its filters (Fig. 2). This lagoon is about 500 feet in length, 28 feet wide, and has an average depth of 4 feet. The average detention time is about 17 hours in winter and 20 hours in summer. Although the plant effluent entering the lagoon is very satisfactory, the lagoon improves it still further. Table 1 shows the work done.

The B.O.D. removal was 32 per cent in winter and 45 per cent in summer; the suspended solids removed was 73 per cent and 51 per cent for the corresponding seasons. It is interesting to note that the D.O. dropped 18 per cent in winter, but increased 28 per cent in summer. In fact, during summer midafternoons the lagoon effluent would contain as much as 21 ppm of D.O., due to the abundant algae growths.

The numerical data do not tell the full story. A lagoon of this type has a tremendous public relations value. This lagoon is actually a beauty spot on the campus. Due to the warm temperature, even during the winter, and the nitrogen value of the effluent, which is used for lawn watering, the vegetation around the plant remains green all year long. The lagoon it-

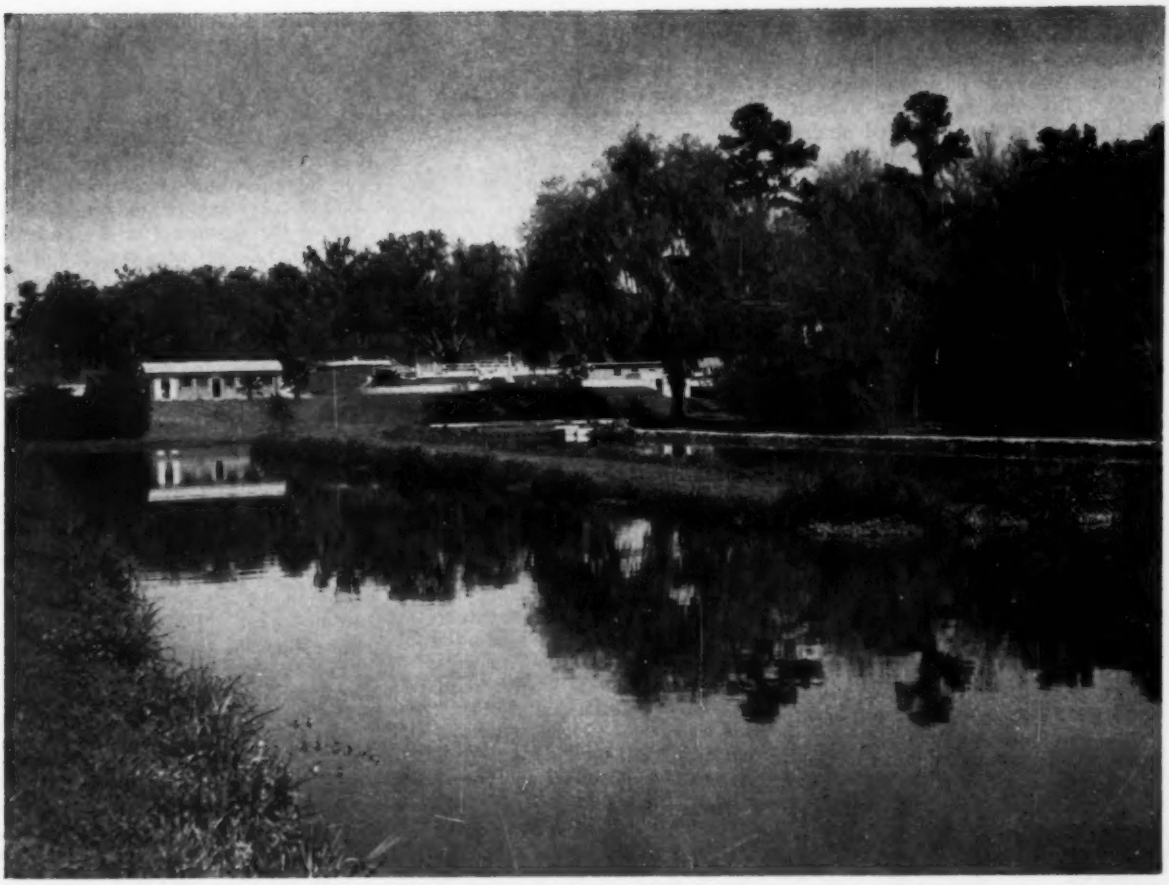

Fig. 2—OXIDATION POND at University of Florida sewage treatment plant. Influent is at upper left, effluent at upper right. Note luxuriant growth on banks, although photo was taken in February

self is a small-scale zoo. At the lagoon minnows, turtles, catfish, alligators, bass, ducks, herons, egrets, and other forms of life have been seen or caught. Naturally, with the high D.O. in the lagoon, no odors have been noticed. It is not at all unusual to see parents bring their children to this spot to show them the "wild life". How many other sewage plants can make this statement?

Lagoons for treating domestic sewage are feasible where land is cheap and available. It is usually good practice to buy more land than immediately required so that as the community grows, adequate treatment may be provided. Lagoons work best where the climate is warm, dry and sunny.

The maintenance of lagoons is simple and inexpensive. The area around the lagoon should be fenced to keep out animals and children. Grass and weed cutting must be carried on so as not to cut down wind action. The dikes must be inspected to prevent failures, break-throughs, or undermining.

One of the questions frequently asked is whether the sludge need be removed from the lagoon and how frequently? In Fessenden, North Dakota, a sewage lagoon has been successfully operated without removing any sludge for 24 years with no appreciable decrease in capacity or efficiency of seepage rates."[16]

Industrial Waste Lagoons

The use of lagoons for the treatment of industrial wastes has been successfully practiced in many locations. A partial list of the various industries that have reported on waste treatment lagoons is given in Table 2.

Industrial waste lagoons operate in the same manner as those treating domestic sewage. One of the most important factors to be kept in mind is that the lagoon will operate satisfactorily only if a balanced diet is available for the microorganisms. This may be difficult to achieve in some industrial waste situations, and some wastes may require the addition of chemicals; for example, some form of nitrogen for wastes predominately carbohydrate. If the diet of the microorganisms in the lagoon is too one-sided, the anaerobes may take over and unpleasant odors may result.

TABLE I
Data on Performance of University of Florida Sewage Plant Polishing Lagoon[5]

	Temp.,	B.O.D., ppm		Susp. Solids, ppm		D.O., ppm	
Months	°F	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.
Jan.-May	73	10.7	7.3	11.	3.	5.6	4.6
June-Aug.	84	5.6	3.0	7.	3.	4.6	5.9

Another factor to be kept in mind, especially when starting a lagoon in operation, is that of letting the microorganisms become accustomed to the waste. This idea is similar to that used in starting an activated sludge plant or a sludge digester. Small amounts of the waste are fed into the lagoon at first, this being increased as the microbial life in the lagoon begins to work and multiply.

One of the determining factors as to whether lagoons or some other form of treatment is adopted is the availability, the cost, and the type of land. Some seasonal industries, such as vegetable canneries, build lagoons to hold an entire season's waste. They rely on some percolation into the ground and some evaporation into the atmosphere during the season. The major portion of waste stabilization occurs in the lagoon after, or during the later months of the season.

One of the reasons for this is that a lagoon, just as any other type of secondary treatment unit, requires a maturing period before it can effectively reduce the B.O.D. During the maturing, with constant flow into it, the lagoon may become devoid of oxygen and require attention. Industries have found that the addition of sodium nitrate is effective in this situation[2, 6, 7]. After this stage however, the lagoon will begin to stabilize the waste and a satisfactory effluent is produced.

Other industries have found that lagoons with an outlet are satisfactory for reducing the pollutional nature of their wastes. One of the citrus concentrate plants in Florida uses continuous-flow lagoons after chemical treatment. The lagoon is 375 feet wide and 2,000 feet long, with an average depth of 1.5 feet. The flow varies between 275 and 400 gpm. The lagoon influent has an average B.O.D. of 4,550 ppm and the effluent averages 1,800 ppm[10]. In view of the large peel oil content of the influent (which has a somewhat toxic effect on the microbial life) this is a reasonable reduction in B.O.D. In this particular situation the addition of phosphate and nitrate has been found beneficial.

For some types of industrial wastes it has been found effective to operate lagoons in series. Two or more ponds are so arranged that the flow from the first enters the second, that from the second enters the third, and so on until the desired degree of removal is accomplished. The basic idea in this type of operation is similar to that of recirculation through a trickling filter. The first lagoon removes part of the B.O.D. load, the second removes another portion of that left by the first, and so forth. This type of operation has been used in the treatment of paper mill wastes[11], vegetable cannery wastes[12], and others.

TABLE 2

Some Industries Reporting Use of Industrial Waste Lagoons

Frozen food processing
Poultry dressing
Cheese
Synthetic rubber
Beet sugar
Vegetable canning
Paper and pulp
Citrus concentrating
Milk and dairy products
Radioactive wastes

It should be pointed out that many types of industrial wastes contain inorganic settleable solids in addition to dissolved or colloidal organic matter. Where lagooning is being considered as a means of treating this kind of waste, it would be advisable to investigate the effectiveness of presettling ahead of the oxidation pond. It has been found that where this was not done the detention time in the lagoon soon decreased due to the volume occupied by the settled solids. This not only causes a reduction in B.O.D. removal, but may mean anaerobic conditions (and odors) in the first part of the lagoon, and further, will lead to more difficult sludge removal and disposal problems.

Summary and Conclusions

To summarize, lagoons or oxidation ponds have been proven successful as a means of sewage and industrial waste treatment. The basic criterion as to whether lagoons or some other method of treatment shall be chosen is an economic one. Where land is cheap, available, and plentiful; where low operation and maintenance is desired; where very little operation is a governing factor, the choice might very likely be in favor of lagoons.

Oxidation ponds, as discussed here, are secondary treatment units, biological in action. Other types of lagoons are in use also; for example, sedimentation lagoons. The oxidation ponds may be so designed as to require no further disposal or they may be designed with an outlet. Rates of evaporation and percolation, winds, rainfall, sunshine, are some of the relevant factors here. Details on loadings, construction, operation, etc., are best determined in each situation. Much detailed information exists in the literature, only a small portion being listed in this article.

Before concluding, mention should be made of the work previously referred to by Parker et al.[8]. During the course of these investigations on domestic sewage, an anaerobic lagoon was set up followed by an aerobic one. They found that the anaerobic lagoon could remove 600 lb of B.O.D. per acre per day in 5 days during the summer (64°F) and 450 lb of B.O.D. per acre per day in the winter (52°F). The aerobic lagoon had a maximum removal at 82 lb of B.O.D. per acre per day, but a loading of only 65 lb per acre per day was recommended for the best quality effluent.

They further decided that for anaerobic lagoons the capacity or detention time was the most important factor, whereas for aerobic lagoons surface area was more important. It would be most interesting to see further work along these lines. This author is currently investigating the disposal of starch desizing wastes from a textile finishing plant along these lines of thought.

The next article in this series will be concerned with some of the newer developments and modifications in the activated sludge process of sewage treatment.

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Trickling Filters And Their Operation

By GEORGE T. LOHMEYER

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■ Although man could be proud of his use of concrete, tile, steel, and power in the construction of trickling filters, the principles of treatment involved have been present since life first appeared on earth. Any stream of flowing water with an ample concentration of dissolved oxygen, and providing the presence of biologically inhibitory substances are sufficiently low, will gradually reduce the quantity of organic matter present, provided no additional pollution is discharged into the stream. This self-cleansing action of the stream is possible through the cooperative efforts of a variety of flora and fauna such as bacteria, protozoa, algae, fungi, worms and insect larvae. These organisms utilize as food, either the organic matter present in the sewage or other organisms which subsist on the sewage solids. The net result is referred to, if it is accomplished in the presence of an adequate supply of dissolved oxygen, as a biochemical oxidation process. A satisfactory biological condition exists when there is an adequate supply of oxygen to support a multitude of aerobic organisms, which use as a good source, either directly or indirectly, the organic matter held in solution or suspension by the flowing stream.

The self-purification factors of a stream, namely, the presence of oxygen, aerobic organisms, and a food supply, are established in the trickling filter. A trickling filter is an artificial bed of inert material called media or aggregate covered with a naturally formed biological slime or zoogleal mass over which settled sewage trickles. The complex population of organisms making up the zoogleal mass consists principally of aerobic forms, those that require dissolved oxygen for their life processes. The proper dissolved oxygen level is usually provided by a natural ventilation system in the filter, which consists of a number of vertical shafts extending from the media surface to the underdrain system. The liquid collected contains organic material consisting of the products of oxidation, some of the various filter organisms, and the finely divided humus which sloughs from the filter media. Actually the trickling filter is not a filter in the sense that particles are filtered or strained out. Since the spaces between the media are large, a mechanical straining action will not result if the media is properly selected and placed. In fact, if a straining or filtering action should occur at any level in the media a severe ponding condition will result.

There is a divergence of opinions concerning the exact action which takes place within the filter. Although it is realized that the liquid passes through the filter in 20 to 30 min, the organic solids are believed to be trapped by the gelatinous slimes on the media and held for days before they are "worked over" by the microorganisms. The organisms in the outer slime layers are known to be aerobic. There is reason to believe, however, that the organisms in the deeper recesses of the filter are anaerobic. In spite of this, the biological action of trickling filters, from the standpoint of efficient operation, must be considered to be a completely aerobic process.

Filter Structure

Although trickling filters are usually classified as either standard-rate or high-rate the two types differ only slightly in physical appearance. Generally, a trickling filter is composed of a distribution system which spreads settled sewage over a bed of media supported by a tile underdrain system. This underdrain system, designed also to provide ventilation, is supported by a floor which slopes to a collection channel. The filter media is generally held in place by a retaining wall. Settleable solids in the trickling filter effuent are removed in final sedimentation tanks.

Distribution System

The early trickling filters were equipped with a dosing siphon which discharged through a distribution system of fixed nozzles onto a rectangular filter bed. It was believed that trickling filters required a resting or "breathing" period between loadings and, therefore, the old standard-rate trickling filter was always equipped with a dosing siphon. Later experience has disclosed that a rest period is not necessary, in fact better operational results are obtained with continuous uniform loading. Furthermore, the fixed nozzle systems required a considerable hydraulic head. Today, trickling filters are generally equipped with reaction-driven rotary distributors which require less head. Occasionally, motor-driven distributors are used.

The general type of rotary or "lawn sprinkler" distributor consists of a hollow vertical center column carrying two or more radial pipes or arms; each arm has a number of nozzles through which the sewage is sprayed onto the filter bed. These nozzles all point in the same direction at right angles to the arms. The settled sewage enters the distributor through a line laid under the filter media. Generally, the lower stationary part of the distributor is separated by a mercury seal from the rotating section, although grease seals are sometimes employed. The rotating action results from the reaction to the discharge through the nozzle orifices. The orifice arrangement is designed for a uniform distribution over the entire surface of the filter. Various types of nozzles are manufactured but the basic purpose of a nozzle is to achieve a distribution of the sewage by means of splash plates or other devices. This results in a slight dissolved oxygen pickup in the sewage entering the filter and a minimum of direct washing of the media. The distributor arms are supported by guy-rods and air release lines are provided at several points on the upper side of each arm. Quick opening gates are provided at the ends of the arms for cleaning purposes.

Media

The purpose of the filter media is to provide a surface on which the organisms living in the filter can attach themselves. Since a trickling filter is made for many years of service the media material should effectively resist chemical and physical disintegration. Large-size gravel, pine slabs, tin cans, and even brick bats have been used successfully. However, blast furnace slag is the generally accepted media because of its strength, lack of fine material, cubical shape, and its pitted surface, which provides a tremendous surface area for the organisms to cling to.

The depth of the filter media may vary considerably (from 3 to 16 ft) but generally it is between 6 and 8 ft. The size of the media is an important

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Close-up view of filter bed showing filter media directly on top of Unifilter Block Underdrain Floor at Sewage Treatment Plant in Worcester, Mass.

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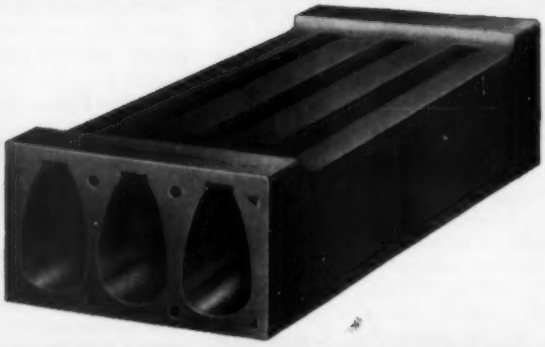

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factor. Although the smaller the media the greater the media surface area, excessively small media will clog readily. It has been reported that the surface area of a filter filled with 2-in. stone is twice the surface area of a filter containing 4-in. stone.

Underdrain System

The underdrain system for trickling filters generally consist of manufactured vitrified clay blocks designed to carry the dead load of the wet media. The purpose of an underdrain system is twofold: (a) to collect the filter effluent promptly and (b) to provide a natural ventilation system. The collection flume is generally designed to flow half-full at maximum hydraulic load so that air can circulate throughout the media. To provide more air circulation, vertical clay pipe shafts are installed to extend from the media surface to the underdrain system, and are placed at regular intervals around the circumference of the filter.

The poured concrete floor beneath the media should be watertight and made as smooth as possible, since a rough floor will collect solids.

Walls

Trickling filters have been constructed without walls, the media graded to a stable slope. Some filter designs have used fencing to retain the media. Accepted practice is to construct walls of reinforced concrete. It is advantageous from the standpoint of plant operation to have solid walls because occasionally filter flooding is a necessity. Although more ventilation is provided without a filter wall, the disadvantages of this type of construction generally outweigh the advantages.

Standard-Rate and High-Rate Trickling Filters

Although the physical appearance of the standard-rate and the high-rate trickling filters closely resemble each other, there is a considerably difference in the loading rates and the degrees of treatment obtained with each. Both filter types are extremely reliable. They have an exceptional ability to withstand overloads and shock loads, and their operation is relatively simple when compared with the activated sludge process.

Standard-rate filters use a dosing tank and siphon to shut off the flow to the distributor when the head falls below the level necessary to rotate the arms. High-rate filters provide for the continuous dosing of the filter. Recirculation of filter or secondary clarifier effluent is provided in most designs to maintain a continuous flow to the filter. Pumps are used and the recirculation system is frequently a proprietary design.

High-rate filters, normally comparatively shallow in depth, recirculate all or part of the filter discharge back to the filter. The recirculated flow may be filter effluent, or secondary clarifier content, underflow or effluent. Recirculation reduces the B.O.D. of the flow to the filter and results in a reduction to a lower B.O.D. than would result from a single passage through the filter.

The standard-rate trickling filter requires a greater volume of media and a larger distributor than does the high-rate filter and accordingly the initial cost is greater. However, the operation cost for the high-rate filter is greater because of the recirculation system required. High-rate filters have an advantage over standard-rate filters in that the degree of treatment can be varied by changing the recirculation ratio (recirculated volume/influent volume).

Both types of filters have certain disadvantages if careful operation is not followed. Nuisances caused by odors and psychoda flies are two of the greatest.

Trickling filter distribution, collection, and pumping systems must be designed to handle the hydraulic loading rates anticipated. At the same time there are limitations on the quantity of organic wastes which can be applied. Therefore, loading rates must also express the organic B.O.D. loading which the filter can adequately handle.

Hydraulic loading rates are expressed as "millions of gallons per acre per day" (m.g.a.d.). Organic loading rates are expressed in terms of "pounds of B.O.D. per day per unit volume of media." The unit volume is designated as "per acre-foot," "per cubic yard," or "per 1,000 cu ft" in the literature.

Table 1 presents data to compare the two types of filters in a number of their principal features.

Types of High-Rate Filters

High-rate trickling filters are generally loaded at 5 to 10 times the average hydraulic and B.O.D. loading of standard-rate filters. A number of patents have been obtained for high-rate trickling filters which involve either a method of spraying the settled sewage over the media surface or a method of recirculation. The following brief comments describe the pertinent features of each patent.

Accelo-Filter

The Accelo-Filter system has a relatively deep media depth, generally about 6 ft. A two-arm distributor is provided and a 2 to 1 recirculation ratio is recommended. The identifying characteristic of the Accelo-Filter is that the filter effluent is returned directly to a headbox where it mixes with the settled influent sewage. This recirculation system provides a means

Table 1
Comparison of Standard-Rate and High-Rate Trickling Filters

Feature	Trickling Filter	
	Standard-Rate	High-Rate
Hydraulic loading (mgad)	Less than 4.0	From 10 to 30
Organic loading, B.O.D. (lb):		
Per acre-foot per day	600	3,000
Per 1,000 cu ft per day	Less than 15	Over 30
Per cu. yd. per day	Less than 0.4	Over 0.8
Dosing interval	Not more than 5 min, generally intermittent but can be continuous	Not more than 15 sec, must be continuous
Sloughing	Intermittent	Continuous
Secondary sludge	Black in color highly oxidized, light fine particles	Brown in color, not fully oxidized, fine particles, tendency to septicity
Effluent	Highly nitrified, into the nitrate stage, 20 ppm or less B.O.D	Not fully nitrified—generally only to the nitrite stage, 30 p.p.m. or more B.O.D.
Recirculation system	Generally not included but can be included if hydraulic loading is not exceeded.	Always included, although in some types recirculation is used only during periods of low flow.

of reducing odors, increasing the concentration of dissolved oxygen, and continuously reseeding the influent sewage with active, hungry organisms from the filter.

Aero-Filter

A low momentary rate of application on a maximum area at one time is the characteristic feature of the Aero-Filter. This is accomplished by furnishing special distributors which provide a "raindrop" application on the media. Filters up to 34 ft. in diameter use a rotating disc whereas filters of larger diameters employs a special 8- to 10-arm distributor, which sometimes is rotated rapidly. Recirculation from the final clarifiers to the filter influent is provided for periods of low flows so that a minimum loading rate of 13 m.g.a.d. is maintained.

Biofiltration

The Biofiltration process is characterized by the recirculation of the filter effluent ahead of the primary clarifiers. This system requires larger primary and secondary clarifiers, but at the same time it provides a better consolidation of the solids in the primary tank. It also provides a highly flexible arrangement for operation of the clarifier. The depth of the filter media is relatively shallow, being 3 to 5 ft.

Other Types

Roughing filters are special high-rate filters used for reducing the B.O.D. of an excessively strong waste to a level which can be handled by conventional treatment methods. The Bio-Activation process utilizes a high-rate filter followed by an activated sludge plant.

Filter Operation

A trickling filter is not an independent treatment unit in itself, but depends on the entire sewerage system. Operational problems of trickling filters can sometimes be traced to faulty engineering, improper construction, or poor operation of the sewage collection system. Inadequate sewer line grades, excessive detention periods in lift station wet walls, and faulty operation of the system can result in a highly septic sewage reaching the sewage treatment plant, especially in warm climates. Septic sewage cannot be readily treated by the biological treatment process which is utilized in the trickling filter.

The primary and secondary clarifiers, and the digester can impair the operational efficiency of the trickling filters.

The supplemental treatment units must be operated so the trickling filter will produce the best results.

Raw Sewage

The raw sewage entering the treatment plant should be as fresh as the design, construction, and operation of the collection system will permit.

Primary Clarifiers

The primary clarifiers should be operated so that:

1. Practically all the grease and floating solids are removed. If these solids are not removed they will clog the filter nozzles and the air spaces between the media. Grease will impair the filter efficiency by covering the zoogleal slimes with a layer which retards the absorption of oxygen, and it is a direct cause of odor.

2. A 30 to 35 per cent B.O.D. removal efficiency should be attained in the clarifier. The lower the B.O.D. of the filter influent the lower will be the B.O.D. of the filter effluent. Every part per million of B.O.D. removed in the primary clarifiers is just that much less load to be handled by the filter.

3. The clarifier sludge pumped to the digester should contain a minimum volume of water. For trickling filter plants without sludge thickeners the sludge solids content should be 3.5 per cent or more. Plants with sludge thickeners will produce a sludge of higher total solids. The ratio of raw sludge per day in gallons versus the influent flow in million gallons per day should be from 4,000 to 3,000 or less.

Any excess water pumped to the digester with the raw sludge will dilute the alkaline environment of the digester. If the digester is upset, the supernatant returned to the plant flow will carry an excess of solids, many of which will pass through the primary clarifiers to the trickling filter, all to the detriment of the trickling filter. The situation is complicated because any excess water pumped to the digester must leave the digester as supernatant.

Digester

The digester supernatant, if it is returned to the plant flow, should meet the following criteria:

1. Contain less than 0.5 per cent solids.

2. Be returned to the plant flow at either a slow rate throughout the day, or at a slow rate during periods of low night flow.

The author is of the opinion that supernatant should be returned to a trickling filter only if the plant is considerably underloaded. Best operation will result when the supernatant is kept out of the secondary treatment units entirely, particularly when the plant is operating at or above design capacity. A number of operators have accomplished this by disposing of supernatant on a partitioned section of an idle sludge drying bed. Another method is to discharge the superatant to the plant lawn. The latter method is excellent for the lawn since supernatant is rich in plant nutrients but irrigation should be practiced only if: (a) the supernatant is in good condition, (b) the lawn is a thick mat or grass, and (c) the method of application prevents surface run-off of the liquid.

Secondary Clarifiers

The secondary clarifier sludge should be completely removed at intervals not exceeding two hours when the temperature is warm. Best operation will result if the secondary sludge is pumped to the primary clarifiers for settling and consolidation before it is pumped to the digester.

Filter Problems and Solutions

Psychoda Flies

The small, moth-like, deceptively fragile fly whose dark brown, worm-like larvae live in trickling filter slimes is, in all probability, the biggest problem for the plant operator, especially during periods of warm weather. Such vast numbers of psychoda flies can inhabit a trickling filter that they are commonly called "trickling filter" flies. No problem will result from their presence if the fly population is held down to only a few flies in the immediate area of the bed. In fact, the larvae perform a useful function in the filter by constantly devouring the dead and dying zoogleal masses. Ponding of the filter occurs rarely when psychoda fly larvae are in a filter.

During the mild winter season experienced in the Southern states, the life cycle of the psychoda fly is from 2 to 3 weeks, but in the warm summer months the life cycle is reduced to 7 days or less. It is during these periods that the flies can emerge in such vast numbers that real nuisance is created.

The adult flies are attracted to lights and for this reason they are a considerable nuisance in the immediate area of the treatment plant. Although the flight distance of the adult psychoda fly is relatively short, they can be wind-blown for a considerable distance. Control measures should be instigated before complaints occur.

In spite of the fragile appearance of the psychoda fly and larvae, the insect in both stages is extremely difficult to destroy. Most control measures depend upon destroying the larvae immediately before the adult emerges. The most severe infestations occur in standard-rate filters but high-rate filters, even those loaded at hydraulic rates of 30 m.g.a.d., may become infested.

The flies can be partially controlled by one or more of the following techniques:

1. Flood the filter for 6 to 8 hr.
2. Chlorinate the filter influent to maintain a 5 p.p.m. residual, thereby destroying the zooglea.
3. Use insecticides such as D.D.T., malathion, and chlordane when the filter is not in service.
4. Use a continuous hydraulic loading to hamper the flies and larvae.
5. Maintain clean grounds with close cropped grass and trimmed shrubbery.

Each of these control measures will, to some extent, upset the biological balance of the filter. Treatment plants with two or more filters can hasten the rebuilding of a "de-psychodied" filter by reseeding with the effluent from an operating filter.

Odors

When excessive odors predominate around a trickling filter it can be assumed that the filter is not operating at its most efficient rate. Trickling filters should be operated so that air circulates throughout the filter media. Foul odors do not accompany a completely aerobic process. One or more of the following conditions could be the cause of filter odors:

1. The influent sewage to the filter could be too strong.
2. An excessive quantity of solids could have been sent to the filter from the primary clarifiers. A foul slug of supernatant is frequently the cause of excess solids.
3. An excessive quantity of grease could be present in the raw sewage.
4. The filter underdrain system could be submerged, thus preventing the free circulation of air throughout the filter bed.
5. Faulty housekeeping could result in the accumulation of moss, leaves, and sticks on the media surface, thereby collecting odor-causing solids.

Although remedies for these causes of odors are obvious, the following suggestions are often worth considering:

1. Recirculation to the filter will wash fine solids through the bed, dilute the influent sewage, and add dissolved oxygen.
2. Reduction of excessively long primary detention periods, especially in warm weather, will aid in maintaining a fresher sewage.

Ponding

A ponded trickling filter is generally caused by an excessive growth of filter slime that has clogged the spaces between the filter media. This excessive growth of slime is caused by loading the filter with a sewage very high in B.O.D. As stated previously, if filter fly larvae are present a ponding condition is extremely unusual.

One or more of the following procedures will often be effective in unclogging the average ponded filter:

1. Reduce the filter influent strength by recirculation.
2. Increase the hydraulic surface flushing rate by recirculation.
3. Flood the filter for one day.
4. Remove the filter from operation for 1 to 2 days so that the zoogleal masses will dry.
5. Chlorinate the filter influent every 4 to 7 days at a rate of 5 ppm for periods lasting from 2 to 4 hr.
6. Stop the distributor over the ponded area.
7. Open the clogged section with a fire hose or by rodding.

Snails

Small brown snails may inhabit trickling filters, particularly in the milder climates. Their presence is of little concern in standard-rate filters or in high-rate filters where the recirculated flow has been settled prior to discharge to the filter. Some difficulty has been experienced in high-rate filters in which the snails were deposited in the mercury seal, thereby causing sufficient friction to stop the rotation of the distributor (S&IW, 27, 3, 377; Mar. 1955). Constant cleaning of the mercury seal and occasional flooding and flushing of the filter have been successful in controlling the snails.

Roaches

The presence of roaches at night around the walls of the filter is a good indication that the particular filter is roach-infested. Although it is true that as long as roaches remain within the filter no harm has been done, it is also true that the roach population could reach a sufficient number to cause a roach migration.

Flooding of the filter is effective in driving the roaches from the filter. The egress of the roaches must be met with an effective spray program using chlordane or some other insecticide (S&IW, 25, 9, 1104; Sept. 1953).

Miscellaneous Operation Details

1. The distributor end gates should be opened daily or more often, if required. When this is done all clogged nozzles should be unplugged by pushing any solids through the nozzles into the arm with a small hand-rod. Any excess slime should be washed from the splash plates and away from the orifice at the same time, and clogged air release lines should be cleaned.
2. The filter underdrain system should be inspected frequently and cleaned by flushing. The underdrain system should be operated so that it flows only half-full during periods of normal flow.
3. The copper cowlings over ventilation shafts should always be in place. An operator who leaves the cowlings broken or the shafts open will soon find them to be the receptacle for filter media.
4. The orifice diameter of the distributor should not be enlarged without first obtaining the recommendations of the manufacturer. The hydraulic design of a trickling filter distributor is not simple.
5. The manufacturer's specifications for the filter distributor should be carefully studied and followed. Generally, the following routine is required:
   (a) Paint the distributor annually using a quality product;
   (b) Lubricate the top bearing monthly;
   (c) Remove, clean, inspect, replace and regrease the top bearing annually; and
   (d) Drain the mercury from the seal every 6 months. Flush the chamber, clean with a caustic solution, and reflush. Clean the mercury by squeezing it through a clean cotton cloth. Weigh the mercury and add the amount needed to meet the specifications.
6. The guy-rod turn-buckles should be adjusted so that the distributor arms remain level in the winter and summer. This applies particularly to large diameter trickling filters.
7. Grease should be removed from the influent line to the trickling filter because it will reduce the pipe cross sectional area.
8. Heavy equipment should never be permitted on the surface of the filter media.
9. Unattended children should not be permitted around a sewage treatment plant.

Every operator of a trickling filter plant will readily admit his trickling filter is the dependable "work horse". However, even a work horse, if provided with the proper care and attention, will be a better producer.

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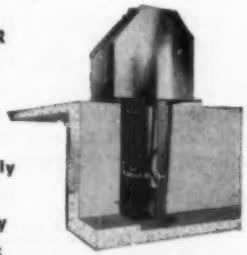

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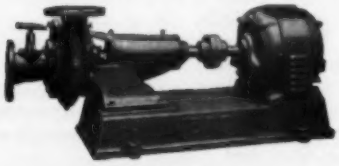

Fig. 5500 Sludge Pump

SLUDGE REMOVAL

POSITIVE FLIGHT CONVEYORS—for rectangular settling tanks.

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SLUDGE AND SEWAGE PUMPS—Fig. 5500 cutting type primary sludge pump. Fig. 5100 enclosed impeller type raw sewage pumps. Fig. 5600 single vane impeller type sewage pumps. Fig. 5400 recirculation pumps. This line of horizontal and vertical pumps ranges in size from 3" to 18" inclusive, in capacity from 40 to 10,000 GPM, and in head from 5′ to 85′.

Send for Bulletins No. 237-A, 250-A, 253-A, 261-A

Total Oxidation Treatment

by R. RUPERT KOUNTZ

Professor of Sanitary Engineering Pennsylvania State University, University Park, Pa.

This is a philosophy and a discussion of a mechanism for the biological oxidation of sewage and wastes amenable to bio-oxidation.

The first premise is the acceptance of the biochemical oxygen demand for its semantic denotation. If the B.O.D. is the oxygen used in the aerobic decomposition of pollution, then a bio-oxidation system must be designed for the magnitude of the B.O.D. value. If complete treatment utilizing total oxidation is desired, then the complete or ultimate B.O.D. becomes the design parameter.

But the B.O.D. test is based on the available *dissolved* oxygen; therefore, the treatment design must be based on *dissolving* a weight of oxygen equal to the ultimate B.O.D. weight. If the waste parameter for B.O.D. is pounds per day, then the oxygen supply design must be in pounds per day. The total oxidation treatment mechanism will be a giant extrapolation of the 20-day B.O.D. test for the waste concerned, and the end-products will be the basic compounds of biology—carbon dioxide, ammonia, and water.

Solids Removal Unnecessary

Assuming an extrapolation of the B.O.D. test to plant scale, there becomes no need to remove any solids before starting the oxidation. It will help, however, if the solids are shredded to a uniform small size before being oxidized. Gravity clarification will only serve to lower the O-R potential of the waste being treated, and inhibit the subsequent oxidation for a time.

There is no good reason for, nor evidence showing the benefit of removing the solid, except for the fact that they will settle if given the chance. Possibly in the days of inefficient devices like stone filter beds, this removal would imply a decrease in clogging. Thus, the second premise is established: solids removal is unnecessary.

An Intermediate Substance

Assuming the influent waste is now entering the oxidation tank (which, of course, by definition), must be continually aerobic, what happens? The organic pollution is enzymatically precipitated by the activated sludge biota and then absorbed for conversion into new activated sludge. This entire metabolic cycle requires four to six hours, depending on the temperature of the waste. Studies of this mechanism have been made (and reported in the literature) which show the yield of new activated sludge to be approximately one-half of the weight of the 20-day B.O.D.

The mechanism now has one phase defined: The input substance rate is related to the production rate of an intermediate substance. The third premise is thus established.

Excess Sludge Production and Removal

What is known of the activated sludge bio-mechanics of metabolism? In conventional plants, "excess" activated sludge is wasted from the system as "excesses" accumulate. Why? Because if it were all returned to the process the oxygen requirement would exceed the aeration capacity of the plant (as presently designed) and anaerobiosis would result.

Suppose the aeration capacity were increased, and all of the sludge were returned. What would happen? Nothing unfavorable to the process, except that the sludge concentration would cease to increase after five or six days. The equilibrium in sludge concentration results because the sludge (which is pure synthetic protein) undergoes oxidation, being converted to its fundamental component compounds. This oxidation rate approximates 20 percent (by weight) per day at 80° F., and occurs continuously in a system which is aerobic. Another phase of the mechanism is ascertained: the rate of removal of an intermediate substance from the process.

At this point in the theory development of the total oxidation process, a retrospective glance is in order: the intermediate product (activated sludge) has a known and definite rate of production and a known and definite rate of removal. These two can and do become equal, resulting in a daily sludge removal rate equal to its daily production rate.

The Oxygen Requirement

To any systems engineer, the only missing item is the energy input to the process. Since this is biological and aerobic, the energy is oxygen. How much oxygen must be supplied? Obviously, the amount supplied must be a weight equal to the 20-day B.O.D. if total oxidation treatment is desired. Unfortunately, the design process weakens at this point, as present aeration systems are rated in cubic feet of air or some empirical parameter of the manufacturer of a proprietary device.

The author has attempted to measure the weight of oxygen dissolved with various devices by operating them at different rates in a catalyzed sodium sulfite solution. These data have been reported previously in the literature. The weight of sulfite oxidized to sulfate should represent the maximum oxygen solution capacity of a device, and at least be comparable to substrate with zero dissolved oxygen.

Process Mechanism

To return to the theory of the process mechanism, it is obvious that only three process units are required: an oxidation tank; an oxygen supply; and a device for removing the activated sludge from the liquid, namely a clarifier. To review the facts and premises, the aeration tank must have a 6-hr. displacement capacity in order to complete the metabolic process, the oxygen supply per day must equal the 20-day B.O.D. weight per day, and the clarifier must be designed adequately for the maximum waste flow rate.

It is assumed that the engineer will ascertain that sufficient nitrogen is in the waste in proportion to the total organic content, and if not will provide for a supplementary supply; otherwise the process can never operate. It is further assumed that for strong wastes the engineer will design his system volume so as to have the equilibrium concentration of activated sludge not exceed 3,000 ppm in order to avoid hindering settlement, thus facilitating clarification.

A number of treatment plants have been built and are operating embodying these principles. Unfortunately the principles have been approached, in many cases, through over-design or by the use of large safety factors and hampered by the inhibition of using conventional systems and parameters. In the present era of high costs and expensive real estate the time has come to evaluate, and to design, waste treatment in the finite terms of a microbiological engineering process, rather than an electrical chrome-plated ox cart.

Activated Sludge Process

And Some Recent Developments

by THEODORE JAFFE

Professor of Civil Engineering, Alabama Polytechnic Institute, Auburn, Ala.

THE ACTIVATED sludge process is in itself a recent development in sewage treatment. It was discovered and recognized as a useful method of sewage treatment by W. T. Lockett in 1913, although a great deal of previous work had been done by Black and Phelps. Since then, many plants throughout the world have employed this process in its original form to produce a clear, sparkling effluent. In recent years many modifications have been proposed attempting to increase loadings, reduce operating costs, improve efficiency, or simplify operation. This article will present some modifications and variations.

Conventional Process

To better understand the changes suggested or practiced, a brief explanation of the "conventional" activated sludge process is in order. The activated sludge process is a secondary treatment process of the biological contact type. This means first, that some form of primary treatment

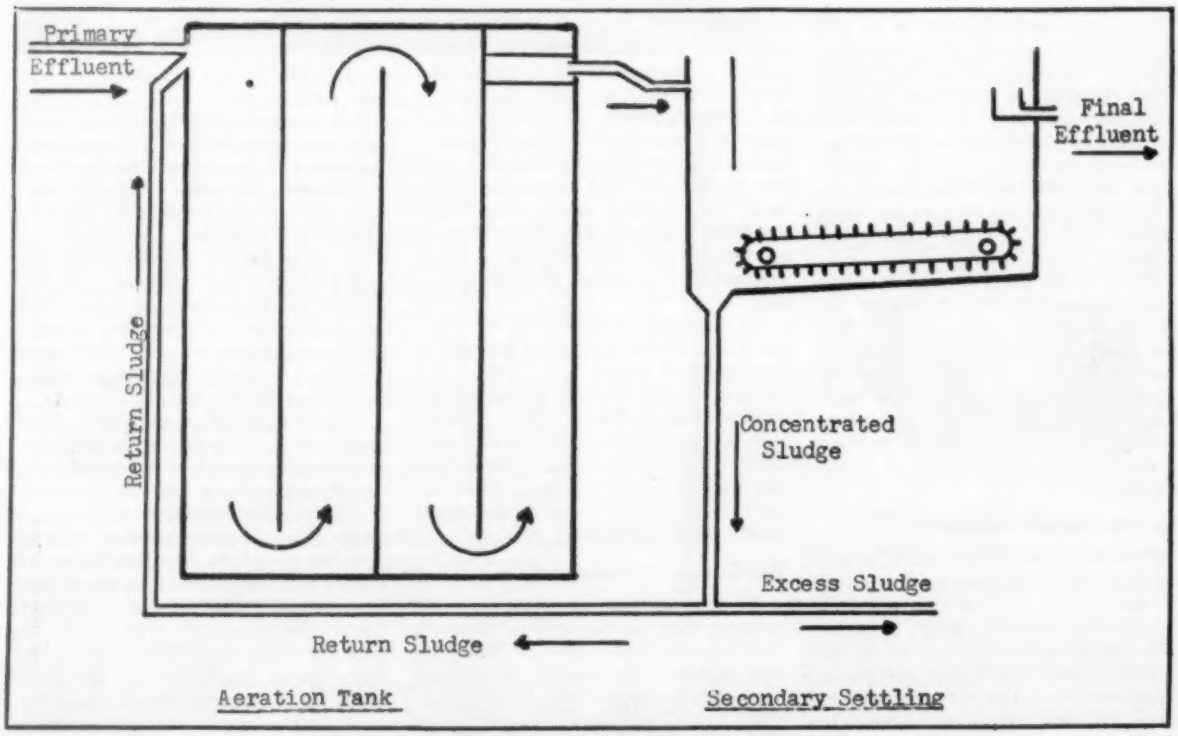

Fig. 1—CONVENTIONAL activated sludge process

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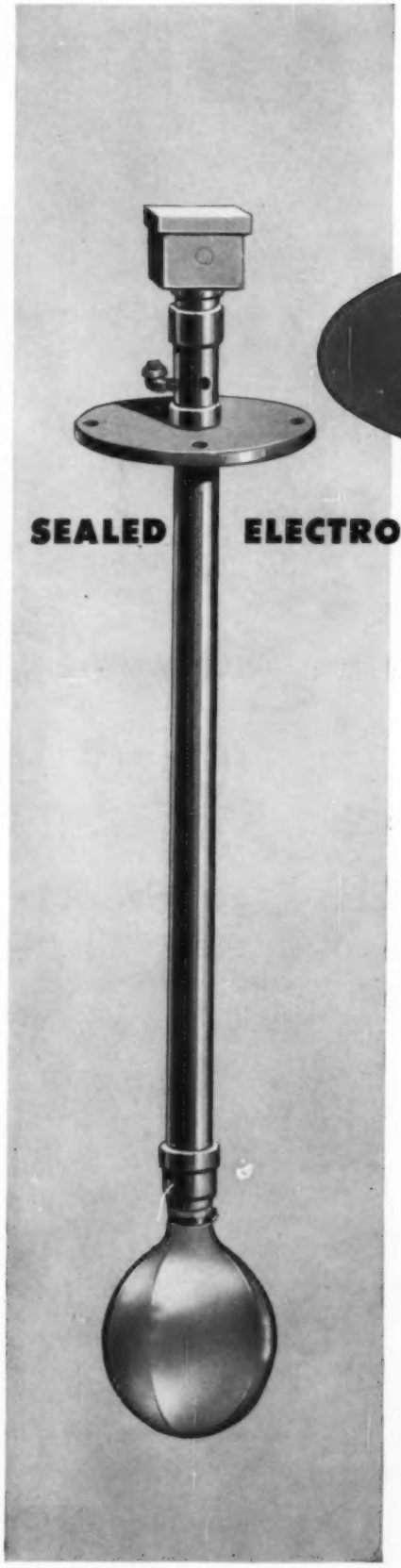

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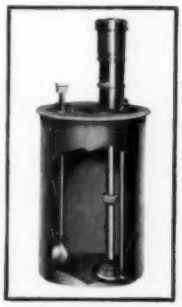

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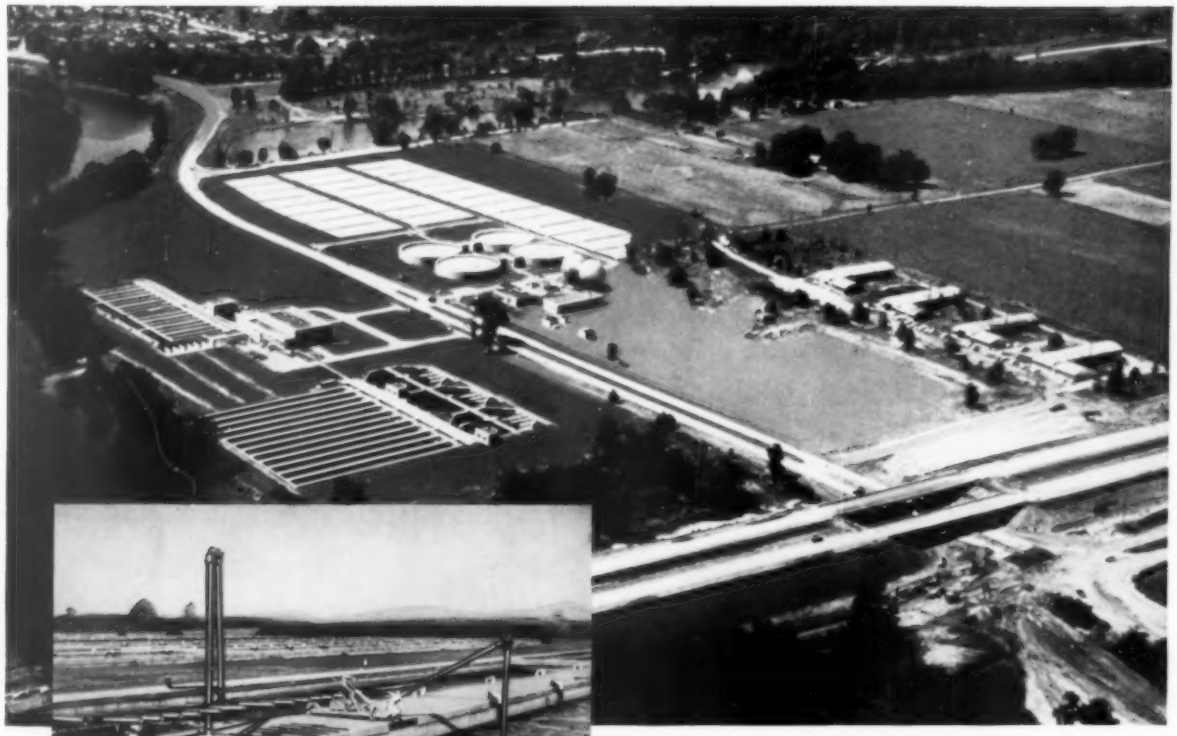

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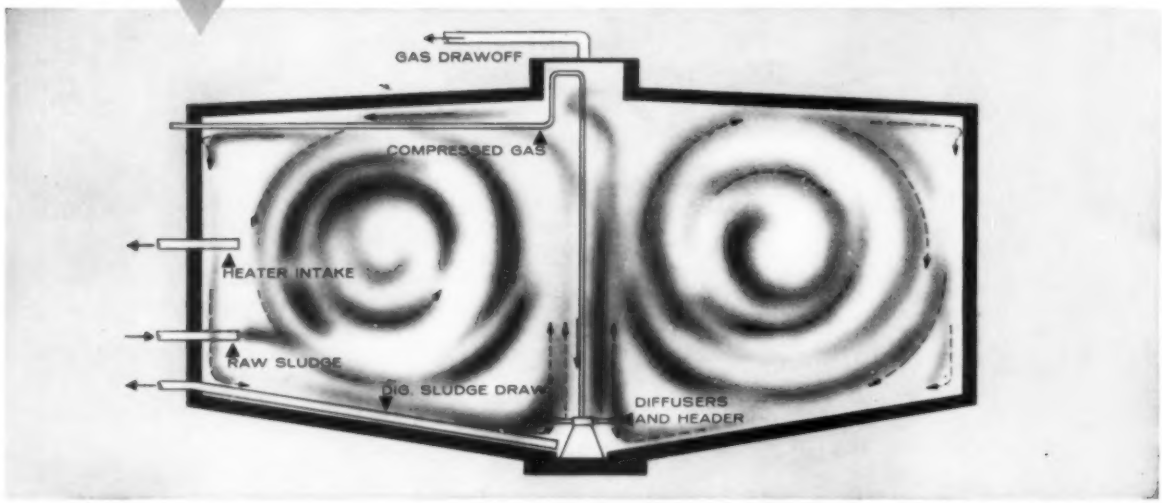

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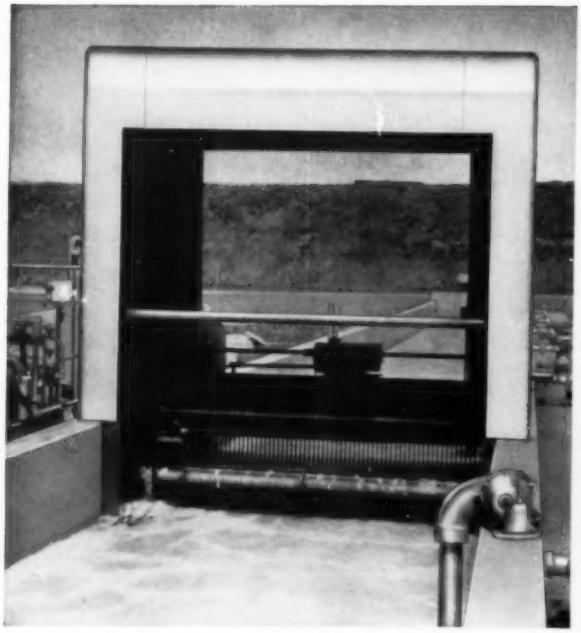

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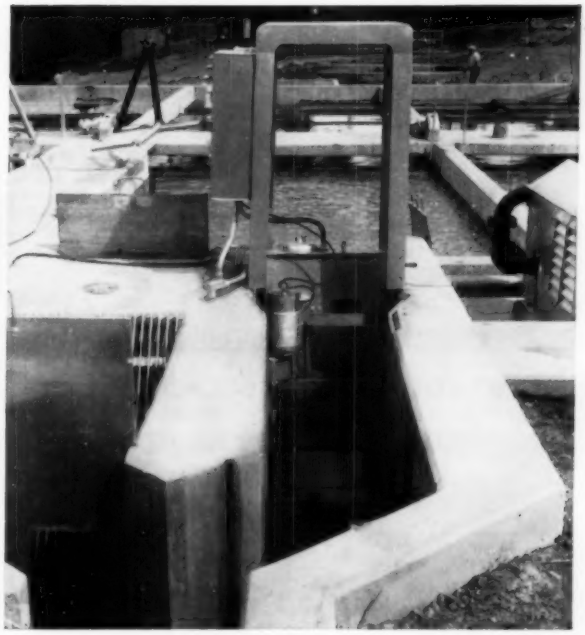

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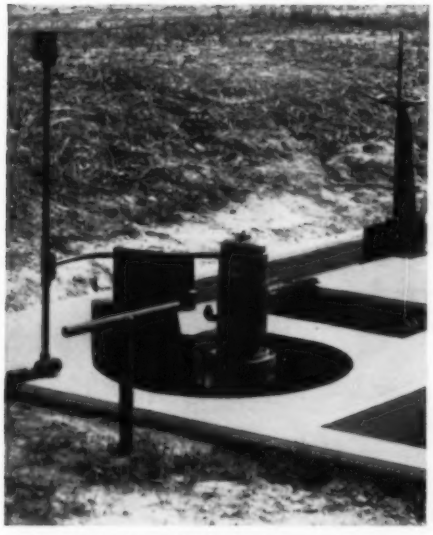

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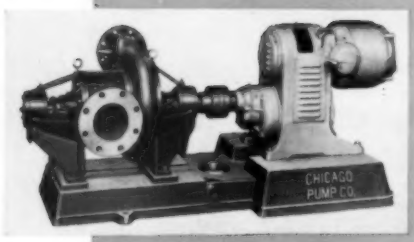

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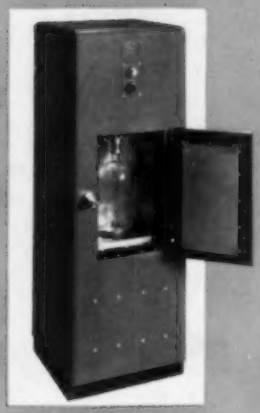

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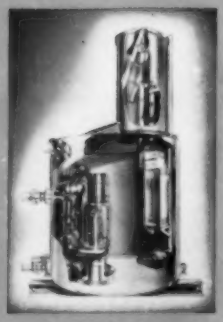

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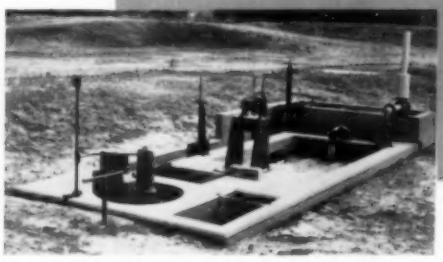

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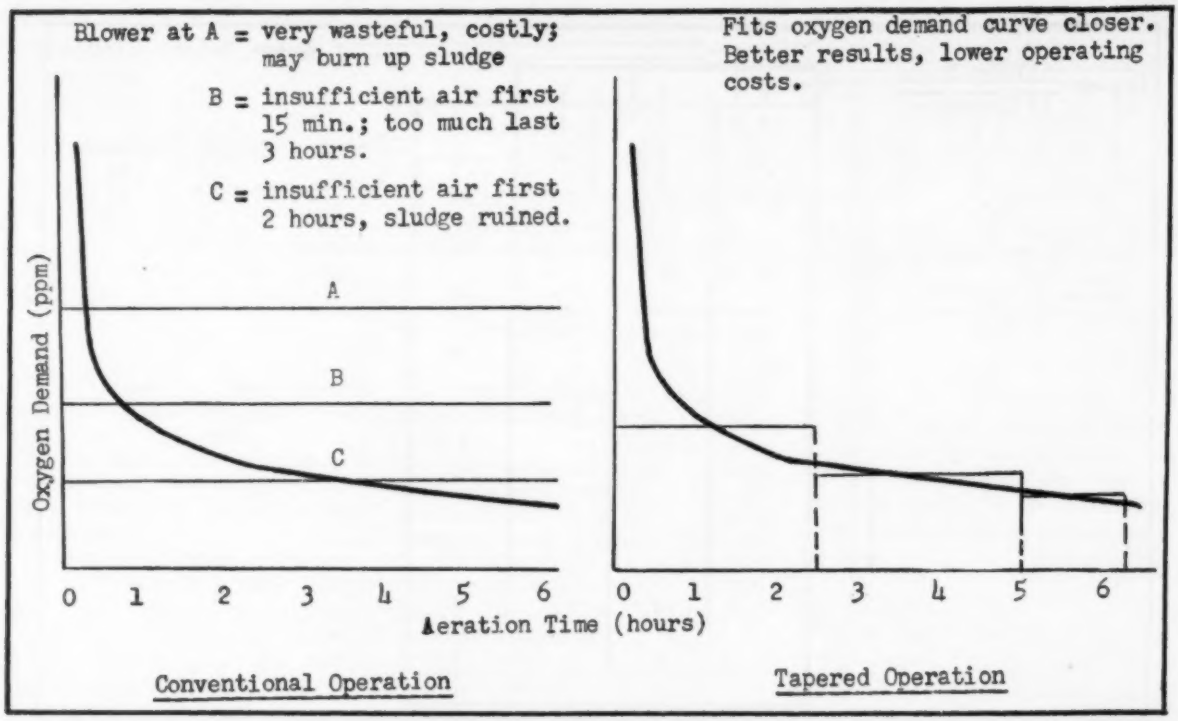

Blower at A = very wasteful, costly; may burn up sludge
B = insufficient air first 15 min.; too much last 3 hours.
C = insufficient air first 2 hours, sludge ruined.
Fits oxygen demand curve closer. Better results, lower operating costs.
Oxygen Demand (ppm)
A
B
C
0 1 2 3 4 5 6
0 1 2 3 4 5 6
Aeration Time (hours)
Conventional Operation
Tapered Operation

Fig. 2—TAPERED vs conventional aeration

or sedimentation will usually be found ahead of the activated sludge units; second, that it is a process in which the sewage (primary effluent) is brought into intimate contact with various forms of biological life. The heart of the activated sludge process is the aeration tank in which the sewage and the microorganisms (in the mixed liquor) are intimately mixed and aerated.

A flow diagram of a conventional activated sludge plant is shown in Fig. 1. It can be seen here that the following units are required: Primary sedimentation tanks; aeration tanks; secondary settling tanks; sludge treatment and disposal. In comparison with a primary treatment plant we have added the aeration units and the secondary sedimentation tanks; in comparison with a trickling filter plant, we have replaced the filter with the aeration units. All other major units are similar.

How does the process work? Any secondary treatment process is aimed at removing colloidal and dissolved matter from the sewage. Usually gravity is employed to remove the settleable and suspended matter in the primary sedimentation tanks. Then the primary effluent, which contains the colloidal and dissolved matter (as well as the remaining suspended matter) is taken to other units where microorganisms, in either trickling filters, sand filters, or activated sludge, complete the removal job. In these secondary treatment units the "bugs" utilize the solids in the sewage as food materials and in the presence of oxygen, convert these unstable, oxygen demanding substances into stable odorless compounds having no oxygen demand. This is secondary sewage treatment.

In the activated sludge process this stabilization of sewage is accomplished by mixing the primary effluent (containing the food-stuffs for the microbes) with the mixed liquor (containing enormous numbers of "bugs") and supplying air either by diffusion or mechanically. The air furnishes oxygen and does a thorough job of bringing the microorganisms into intimate contact with their food. After about four to six hours aeration, the entire mixture is removed to the secondary sedimentation tanks where a separation of liquid and solids occurs. The liquid is removed as the plant effluent and can be discharged—usually after chlorination.

The solids settling in the secondary tanks compact somewhat, and are split into two portions—excess or waste sludge, and return sludge. The excess sludge may receive further dewatering and then be disposed of by any of the conventional methods. The return sludge is recycled back into the aeration tanks to be used again in the adsorption and clarification process. It is this return sludge combined with the primary effluent that is termed the mixed liquor.

In this manner, the activated sludge process will remove about 90-95 per cent of the B.O.D., and about 95-98 per cent of the suspended solids from the raw sewage. It will produce an effluent containing from 10-20 ppm of B.O.D. and suspended solids. These are average figures to be expected for efficiently operated plants.

As this conventional method of activated sludge treatment came into more common use, various modifications of the process were tried. Some of these were not successful, but other variations have proven useful. In general, these variations may be divided into two categories: (a) modifications of operation while employing the same basic structures; (b) those employing modifications of the basic structures.

Modifications of Operation

In a diffused air activated sludge plant, one of the largest operating cost factors is that of air. Early in the history of the process two different approaches were conceived to reduce this cost. One of these led to the "Tapered Aeration" process, the other to "Step-Aeration."

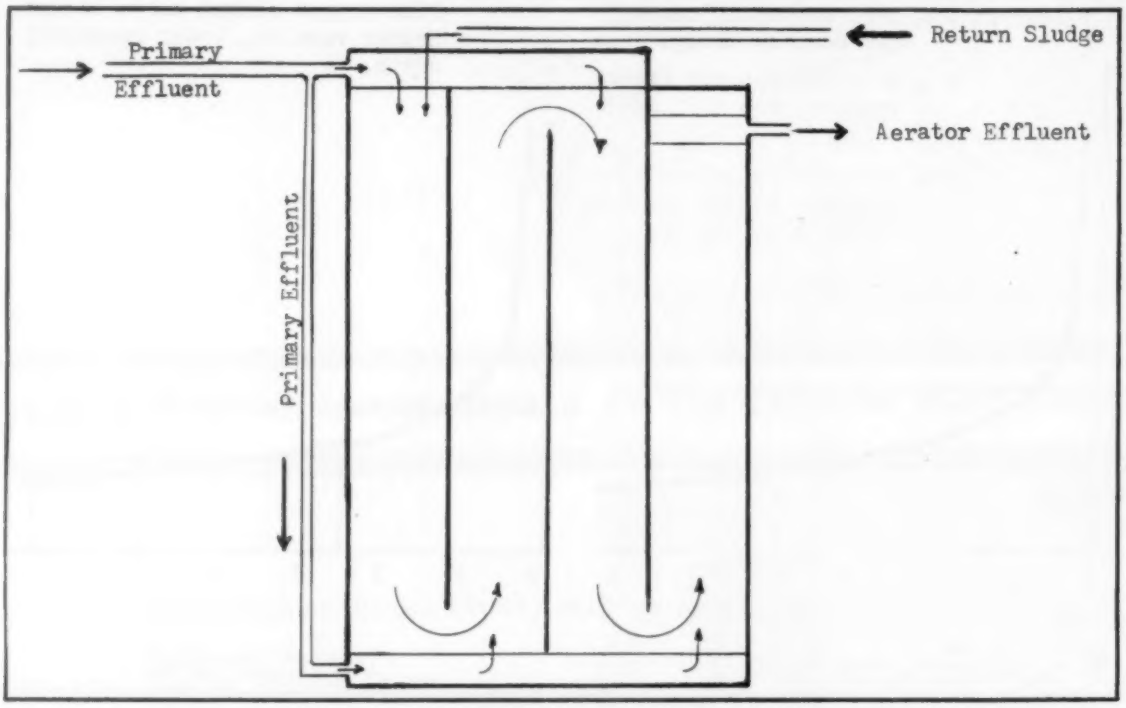


Fig. 3—STEP-AERATION

Tapered aeration was based on the knowledge that the oxygen supplied to the aeration tanks is not utilized at a uniform rate throughout the tank (Fig. 2). During the first two hours about 40 to 50 per cent of the air is required, 28 to 31 per cent in the second two hours, and 20 to 29 per cent in the third two hours, where six hours of aeration are provided. On this basis, it was proposed[8] that the air supplied be made to conform to these requirements. The air supply would be adjusted either by increasing the diffuser area at the inlet end, or by using a large amount of air at the inlet and smaller amounts along the tank. The advantages claimed for this modification are more economical operation and greater control of the process.

The Step-aeration process also seeks greater economy of operation and reduction of cost, as well as better control. In a conventional type aeration tank, where the entire load is introduced at the inlet, it has been found that for about the first quarter or third of the tank, the dissolved oxygen content of the mixed liquor is often zero. Apparently, although sufficient oxygen was supplied, the bugs simply could not handle the load. They could work on the organic matter at a certain maximum rate, and could not be pushed away further.

With this idea, it seemed reasonable to add only a portion of the load at the inlet, another portion at the quarter or third point, another further on and so forth, (Fig. 3). This would serve several purposes—(a) the microorganisms would be working at a more uniform and more efficient rate; (b) there would be no

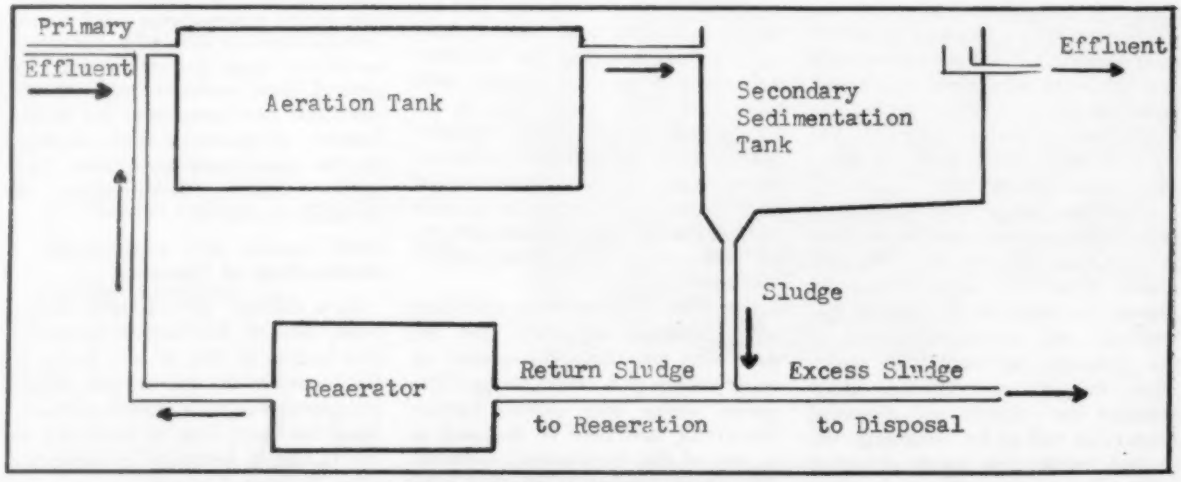


Fig. 4—REAERATION of sludge

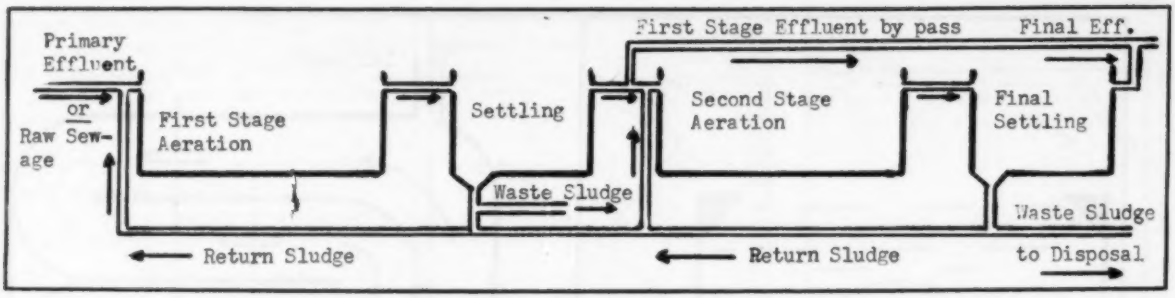


Fig. 5—TWO STAGE aeration operation

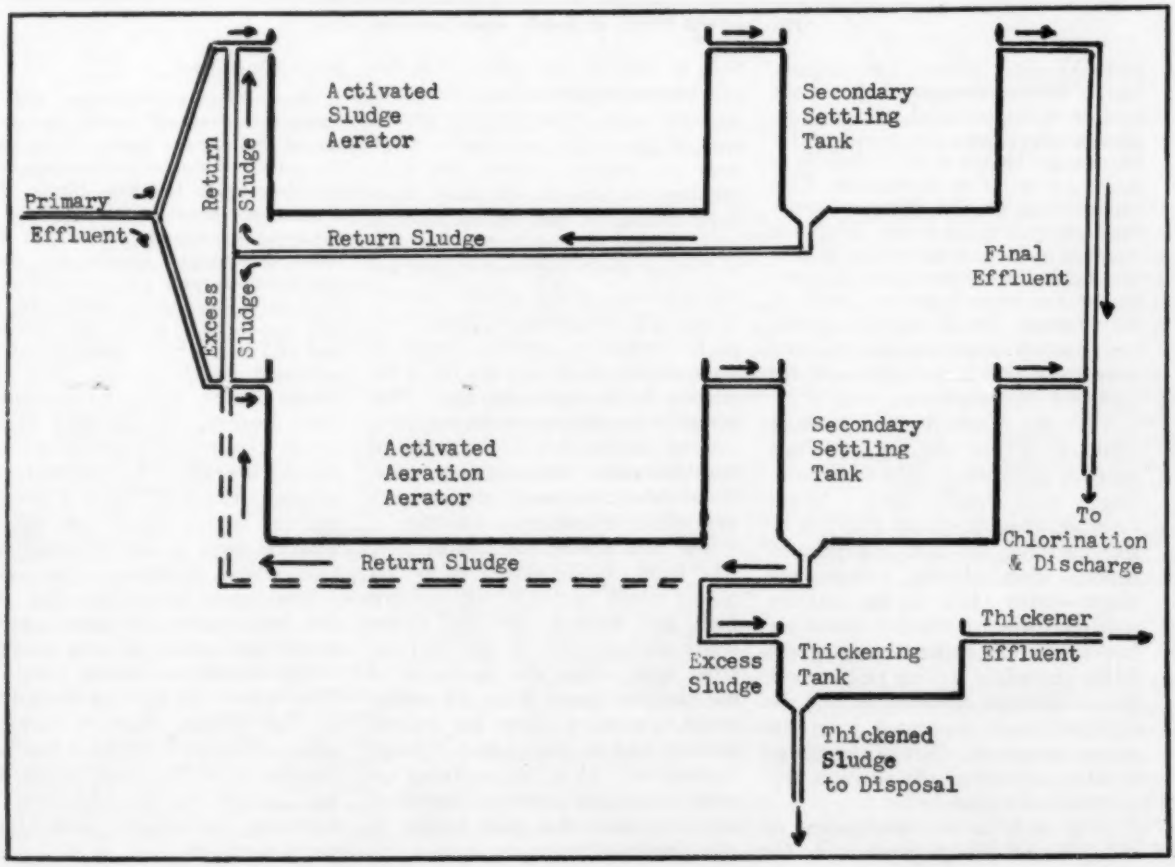
zero D.O. spots; (c) better control with a more uniform air supply would be possible; (d) greater economy since the bugs would be utilized to better advantage—no more too much and too little food. This is the step-aeration process[13].

Another modification of the activated sludge process is called "High Rate" or "Low Solids Activated Sludge Treatment" and was reported by Setter and Edwards[12] and others. The high rate refers to a shorter aeration period of about two to three hours, and a lower air input of 0.5 cu ft per gal. The low solids refer to the smaller amount of sludge returned to the aeration tank. This may be as low as 10 per cent of the sewage flow, compared to the usual 20 to 25 per cent returned in the conventional process. Since a smaller amount of sludge is returned, the suspended solids in the mixed liquor of the aeration unit is kept below 800 ppm as compared to 2000 to 3000 ppm in the usual method.

What results can you expect from this modification? The B.O.D. and suspended solids removals will be smaller, but this high rate-low solids method is recommended as an intermediate form of treatment. It is designed so that any degree of stabilization of sewage can be given between that produced by primary treatment and that from the conventional activated sludge process, at a low cost.

Two Phases to Activate Sludge Process

The activated sludge process basically consists of two distinct phases. When the primary effluent is mixed with the returned sludge in the aeration tank the first phase, that of ad-



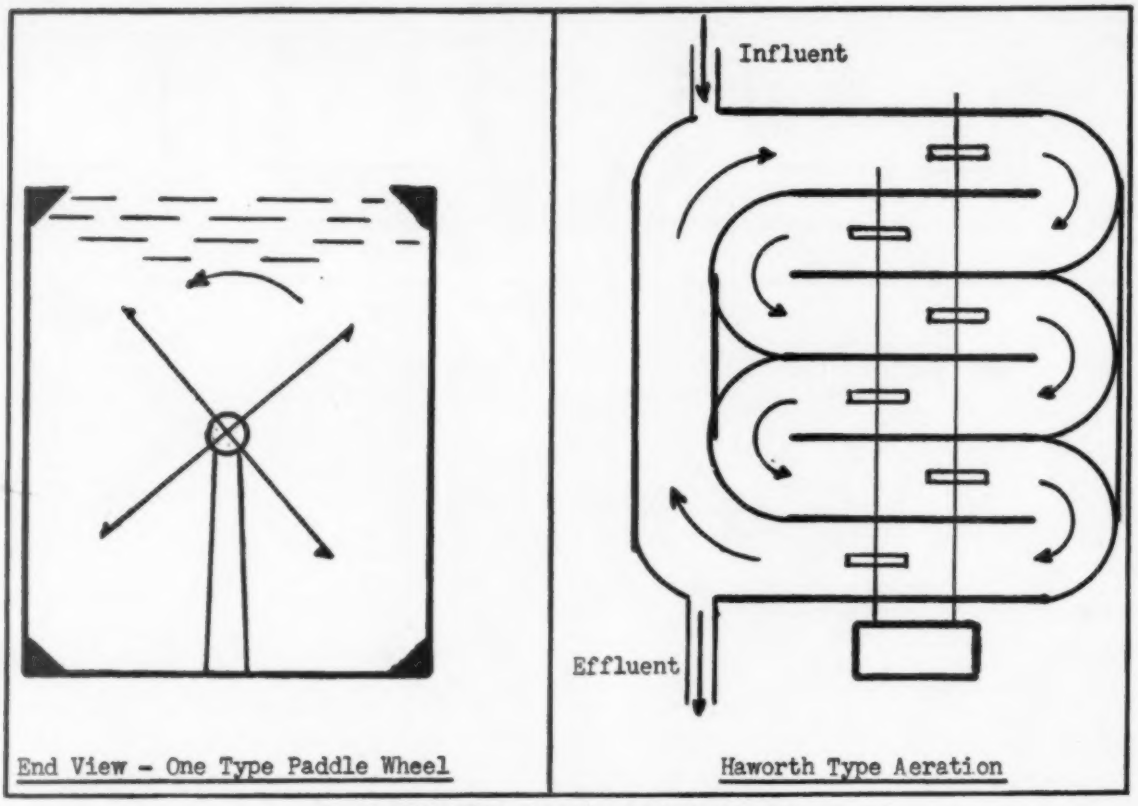


Fig. 7—TWO TYPES of paddle wheel aeration units

sorption takes place. The organic matter of the sewage sticks on the surface of the bacterial masses (zoogleal masses), and as a result of this the sewage begins to look clear. It is no longer milky in appearance. This clarification of the sewage usually takes about 1 to 1.5 hours. While the zoogleal masses are adsorbing all they can hold, the microorganisms begin to eat the organic matter stuck to their homes. This eating is an oxidation process requiring oxygen, and constitutes the second phase of the activated sludge process.

Since the organisms have a maximum eating rate, and since this rate depends upon many factors, the oxidation stage usually takes a longer time and requires closer attention by the operator. In the conventional process most of this action—both stages—takes place in the aeration unit, and usually requires about six hours. From here, the mixture is sent to the secondary settling tanks where the stabilization is completed and the clarified liquor separated from the sludge by gravity. Part of the sludge is then recycled to the aeration unit as previously described.

Very early in the development of the activated sludge process, as far back as 1917, it was shown that the two phases could be acomplished in separate tanks. What was the advantage of this? The adsorption stage does not require oxygen; the only requirement here is adequate, thorough mixing of the sewage with a good, hungry, return sludge. The second phase above required oxygen for the oxidation of the organic matter. If now, the two phases or stages were to be separated, couldn't there be some saving of air and thereby a reduction in the operating cost? This would be possible except for one thing —if we supplied air for oxidation in the secondary sedimentation tank, the air would seriously interfere with the settling efficiency.

The idea needed one further step. The fresh, young sludge to be returned could be taken off into one tank and aerated; the old, excess waste sludge could be run into another tank where the separation of the clarified liquor from the sludge could take place. Now the process worked and it was called "Sludge Reaeration" (Fig. 4). There are many other trade names associated with this basic idea, each having its own variation[14].

Stage Operation

One further modification, that ot "Stage Operation," need be mentioned. At various times in the past, the activated sludge process has been combined with trickling filters. The filters have been used both ahead of the aeration units and after them. The main advantages sought by these combinations were (a) reduced aeration costs through allowing the filters to do part of the purification, and (b) less critical operation of the activated sludge process. Activated sludge is easily upset by variations in flow, loading, or character of the waste. This requires careful and continuous operation. By preceding the aeration units with filters, a smoothing out of the waste entering the aeration units is accomplished, and less critical operation is necessary.

The name "Stage Operation" has also been applied to sewage stabilization by means of two activated sludge systems in series (Fig. 5). This system has had but limited use in the United States[11], although somewhat more experience has been reported from European plants. Imhoff claims[5] this procedure has the following advantages over single stage operation:

(a) The excess sludge contains less water, has smaller volume, and the first stage sludge settles well.

(b) Requires smaller aeration units.

(c) With a by-pass around the second stage, any degree of partial purification is possible.

(d) Plant operation is easily adjusted to shock overloads.

A somewhat similar system has been employed at the Wards Island Plant by Chasick, who calls his modification "Activated Aeration"[2] The process is primarily aimed at overloaded conventional activated sludge plants and although the amount of over-all removal is somewhat reduced, the effluent quality remains high (about 31 ppm of suspended solids and B.O.D.—nine months operation). By varying the operational factors, it is thought, that efficiencies between straight aeration and full activated sludge can be attained.

Briefly, the process consists of dividing the treatment plant into two operational units (Fig. 6). The flow pattern of the return sludge remains the same; i.e., from the settling units of the group to the inlet of the aeration tank. The excess sludge from the first group however, is pumped to the aeration unit of the second instead of being drawn off for disposal. Since this sludge still retains its "active" condition this is utilized, and assists in the stabilization of the sewage. The excess sludge from the second group of units is finally wasted.

The following additional advantages are claimed for this process:

(a) Reduced air requirements; therefore lower power costs.

(b) Small volumes of excess sludge; therefore smaller digesters.

(c) Possibly greater gas production.

Modifications of the Basic Structures

Early in the development of the activated sludge process, it was suggested that one way in which the operating cost might be reduced would be to mechanically mix the contents of the aeration unit. Since a large proportion of the air supplied is required for mixing, it was thought that operating costs would be considerably less. To accomplish this, paddle wheels were placed in the aeration tanks (Fig. 7). These were rotated in the direction of the rising air-liquid mixture, and in other installations were rotated against the rising air-liquid mixture. This method was called mechanical agitation as contrasted to the diffused air method.

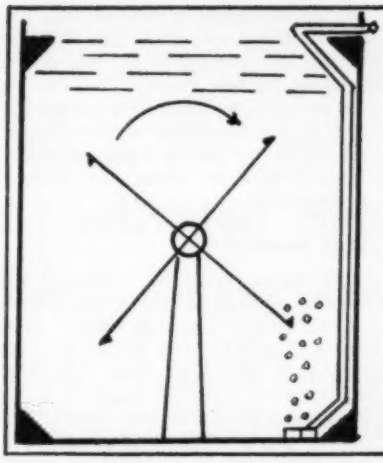


Fig. 8—PADDLE wheel and air type aerator

Fig. 9—BRUSH type aerator

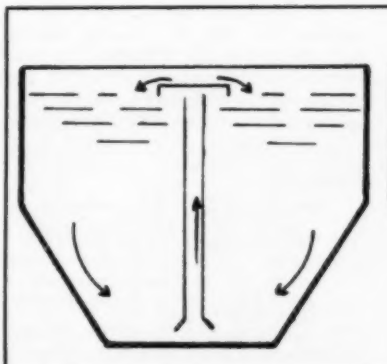


Fig. 10—SPRAY type aerator

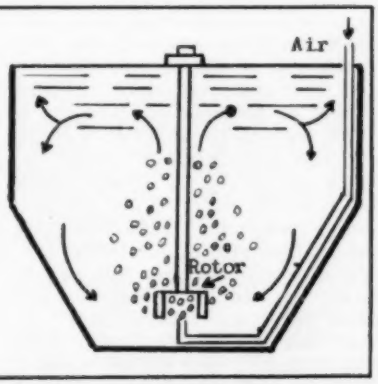


Fig. 11—ROTOR-DISPERSER aerator

One large plant in Sheffield, England[4] was constructed using this paddle-wheel principle.

Another early modification was tried at several plants, notably one in Germany[6]. This was a logical development from preceding methods, in that it combined air diffusion with paddle-wheel agitation. A commercial unit employing this method is shown in Fig. 8.

Attempts have been made to utilize atmospheric oxygen instead of compressed air. The unit devices employed have varied; some types use the same mechanism for circulation and aeration, e.g. the Kessener system (Fig. 9); others employ a mechanical circulation system and a spray or thin-film effect for aeration (Fig. 10). Another design in which the air is dispersed mechanically by a rotor (Fig. 11) which also assists in circulation has been described by this author[7].

Many of the equipment manufacturers have one or more methods of sewage treatment employing air and mechanical circulation. These are known by various trade-names, and are commonly spoken of as "package units." Many of these attempt to treat the raw sewage without any preliminary settling, while others find it advantageous to settle the sewage first. The direction of flow in these units is usually vertical—either up or down flow (Fig. 10 & 11). In the "package-unit" type of plant air is usually supplied either by some form of surface or thin-film contact with the atmosphere, or by introducing compressed air below the liquid surface and using an impeller or rotor to achieve air dispersion, mixing and circulation.

Diffuser Equipment

Many of the developments in the activated sludge process in recent years have sought to obtain greater efficiency through better means of aeration. A great deal of attention is now being paid to the devices used to supply air in the aeration tanks. The usual method has been to force

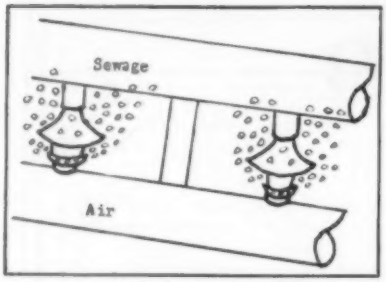


Fig. 12—IMPINGEMENT type aerator

air through porous diffuser plates. These would often become clogged and were quite difficult to clean. New York City has found that spalling (oxyacetylene flame cleaning) of the aeration plates, in place, was effective although in some plants it was necessary to follow the spalling by a jet wash[3].

One of the recent devices attempting to overcome diffuser plate troubles is the plastic-wrapped tube. This consists of a corrugated, stainless steel inner core over which is wound a layer of plastic cord. The air is blown through the inner core of the steel tube and distributed to the diffusing surface through large multiple outlets in the valley of the corrugation. Although some surface clogging due to slime growth does occur after use, it is claimed that this can be easily removed by a high pressure water jet system[1]. When these diffuser tubes are mounted in a swing type assembly, they can be raised to the tank wall for cleaning without any interruption of operation.

Another development along these lines is the jet or impingement type of aerator (Fig. 12). In this system a double set of perforated pipes is used, one placed directly above the other, parallel with the length of the aeration tank and close to the bottom. The mixed liquor is brought in through the upper pipe; the air through the lower. These impinge or are forced against a cone or disc. The air is dispersed into fine bubbles, which are entrained by the downflowing mixed liquor. Due to the air pressure, agitation is accomplished and by the lift effect of the released air in the air-mixed liquor combination, circulation along the tank is achieved.

Dual Aeration

A recent paper[9] has proposed still another modification in aeration technique, called "Dual Aeration." Here air is supplied at two points in a conventional type tank (Fig. 13). Part of the air is supplied adjacent to the tank wall at about one-third of the liquid depth. This is called "distributor air" and is intended to create maximum turbulence. The turbulence, in turn, is intended to "increase oxygen uptake from the air above the liquid surface and also increases the rate of oxygen absorption from the air admitted in small bubbles near the tank bottom"[10]. This bottom air is supplied by diffusers as shown in the figure. The direction of flow in the tank is determined by the location of the diffuser in relation to the distributor. When the diffuser is on the same side as the distributor, "parallel" flow is obtained; with the diffuser diagonally opposite the distributor, "counterflow" results. This latter type of flow is suggested for the usual aeration tanks.

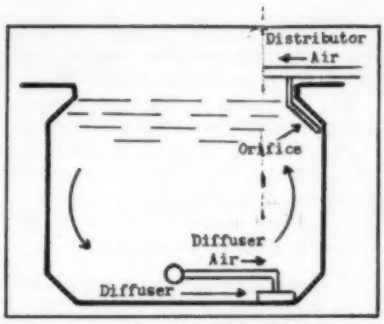


Fig. 13—DUAL AERATOR

Compressed air has many uses in sewage treatment other than in the activated sludge process. These auxiliary uses of air will be discussed in the next article in this series.

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Frothing In Activated Sludge Plants

Causes and possible cures for frothing in aeration tanks

by ANTON E. SPARR

Superintendent, Bay Park Sewage Treatment Plant, Suffolk County, N. Y.

PRIOR TO 1947 the only foaming that caused concern among sewage treatment works operators was associated with digesters. Since then, foam of a different type has become an increasing problem in the activated sludge plants. This type of foaming is also called sudsing or frothing. Simultaneously with the development of frothing of aeration tanks, but not immediately apparent, there was an increased air demand, expressed as the air ratio.

Causes of Foaming

The cause or causes of aerator frothing are still debatable. Many operators believe that the foaming agents added to many of the popular detergents give rise to the frothing. They point out that frothing was not noticed until the synthetic detergents started to gain popularity.

Another indicator was the experience at Mt. Penn, Pa., in 1947. Here foam did not appear on the aeration tank (mechanical type) until the day following the sales promotion distribution of a synthetic detergent. The initial violent foaming—a 5-foot blanket—gradually subsided until only a small quantity was observed at the thirtieth day.

The addition of the Proctor and Gamble Company's "Tide" to the influent end of the aerator at the San Antonio, Tex., plant in 1951, without raising the foaming level, has been used to exonerate syndets. It is believed that at the high levels added the detergent may have had a foam-depressing effect.

Another experience with "Tide" was contrary to that at San Antonio. This "Tide" was introduced in the Motherwell, Scotland, area in 1952 (it is assumed that it was similar to the American "Tide"). Coincident with its introduction, a marked increase in froth accumulation—" . . . reached a 14-foot height above water level"—was noted on the aerators of the local treatment works.

The foaming or frothing agent associated with aerator frothing does appear to have stability, as indicated from the experience at both the Tallmans Island and Bay Park plants. The final tank effluent at both plants must drop several feet under low tide conditions. Under these circumstances violent frothing takes place, even though the foam was effectively controlled in the aeration tanks.

Also, at the Bay Park plant prior to 1956 one of the two aerators was idle and about two-thirds full of ground water. During the periods when the foam in the adjacent aerator was not under complete control, some of this foam was blown into the idle unit. Each time blower tests or blower engine tests were made, it was necessary to bypass the surplus air into the idle aerator, resulting in voluminous foam production.

Similar foaming was noticed when digester supernatant dropped several feet.

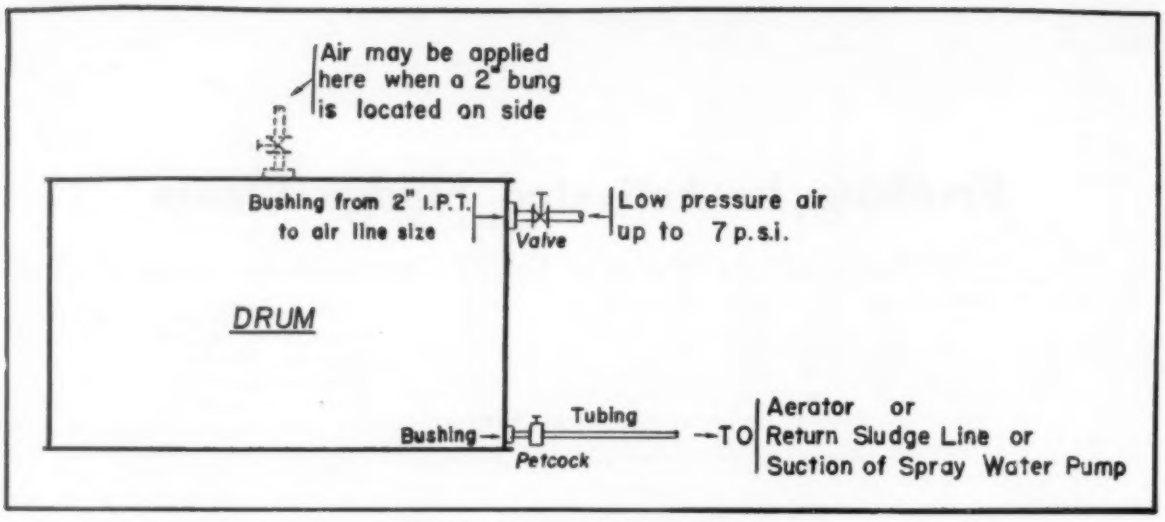
In addition to demonstrating the stability of these foaming agents, these experiences also indicated that agitation is necessary for foaming. Both mechanical and diffused air aerators require agitation to carry on their several functions; the increased air demand indicated earlier causes greater agitation, with a greater tendency to foam production. Much of this increased air demand is due to the decreased efficiencies of the preliminary settling tanks and the increased grease content of the settled sewage—both caused by detergents.

Good Looks- -Temporarily

When first seen at a sewage treatment works, foam presents a pleasing effect. In summer it often appears to be a misplaced snow scene. Dye wastes add to the beauty.

Despite its pleasing appearance, however, foam is undesirable because of the dirt and grease entrained in it. When the foam bubble bursts, a dirty greasy deposit is left. This greasy material is difficult to clean off, mars the appearance of plant buildings and roads, makes walks and guardrails dangerously slippery, kills landscaping, and contains harmful organisms. The sun's action on this material will cause it to give off foul odors, resulting in complaints. Unfavorable publicity also results when wind picks up foam and carries it to neighboring homes, with the attending grease deposits.

Foam blankets up to 14 feet in height have been reported. Such accumulations interfere with the proper operation of aeration tanks in two ways. First, the blanket hinders the necessary oxygen absorption from the atmosphere by shielding the liquid surface. In diffused air plants this necessitates an increase in the blower output to supply the oxygen deficiency. In mechanical aerators, shielding of the liquid surface from the major source of oxygen could be dis-


Air may be applied here when a 2" bung is located on side
Bushing from 2" I.P.T. to air line size
Valve
Low pressure air up to 7 p.s.i.
DRUM
Bushing
Tubing
Petcock
TO
Aerator or Return Sludge Line or Suction of Spray Water Pump

SIMPLE low-pressure defoamant feeder

astrous. The second interference factor is that foam covering all or almost all of the surface does not permit an operator to make the necessary visual inspection for air distribution along the surface of a diffused air aerator.

Foam Control Measures

The health and physical hazards, the unsightliness of residues, the obnoxious odors, the unfavorable publicity, and the interference with oxygen absorption, are among the many unpleasant factors associated with foam and indicate the need for its control.

All of the control measures now utilized effect a destruction of the foam, or prevent its formation, or both. These include raising the suspended solids level in the aeration tanks, using chemicals to act on the foam, and beating down the foam with water sprays.

Maintenance of High Aerator Solids

Eliassen has pointed out (*Wat. & Sew. Wks.*, May, 1952) that syndet molecules align themselves at the water surface of dirt or grease particles. It also was indicated that large numbers of these molecules are required to keep a particle in suspension. The addition of sufficiently large numbers of particles in the foam of suspended solids to which the free syndets may adhere, explains why raising the suspended solids level in aerators often results in adequate control.

Nevertheless, the practice of raising the suspended solids level for foam control means altering the original design considerations. At the Cranston, R. I., plant the solids level was raised from 1,250 ppm. to 3,000 or 3,500 ppm. before control was achieved. At others, a more modest increase met with happy results.

In still other plants, including the Bay Park works, changing of operations from the original design resulted in no change in the foaming, even in cases where the solids were raised to 3,500 ppm.

As experienced at Cranston, the raising of the solids level results in an increased air demand. The cost of supplying the additional air required for the increased solids may be more than when other methods or combinations of methods are used for foam control because the power requirements for aeration in diffused air plants represents 60 to 70 percent of the total power demand. The air requirement to maintain the higher solids level necessary for foam control may exceed the plant's blower capacity, as happened at the Motherwell plant. There, the level was raised from 760 or 1,500 ppm. to the limit of 2,450 ppm. without control.

Such an experience is very likely to occur in a plant designed for high-rate (modified) activated sludge operation, because a marked increase in solids will change the plant to conventional operation with its higher air requirements. Furthermore, higher suspended solids content in an aerator results in a higher sludge age and may bring about floc disintegration or result in solids with poor settling qualities. Nevertheless, limited use can be made of this tool for foam control when supplemented with a chemical defoaming agent or a water spray. A study of the economics involved will point to the most economical combination of control measures.

Defoamants

Use of "foam killing" chemicals in aeration tanks is gaining ever-increasing favor. These chemicals, called defoamants or defoamers, when applied at points of excessive foaming should quickly effect a marked reduction in the volume of foam. This rapid reduction of foam volume is referred to as the "knockdown." An effective defoamant also will prevent a build-up by acting on the foam beginning to foam at the liquid surface.

Because frothing is a surface phenomenon, a defoamant, to be most effective, *must be able to remain on the surface during much of the aeration period.* To be able to do this, a defoamant must have a specific gravity less than that of water, and must be insoluble in water. Water soluble defoamants can be used, but they usually result in a high performance cost because of the high dosages required.

Defoamants can be applied in various ways and at those locations where control is required. The old standby, the drip can, is simple to make and can be moved about easily. It does have the disadvantage of having a varying discharge as the level in the container changes and as the viscosity of the liquid changes.

An inexpensive modification of the drip can (see accompanying sketch) permits much better control. In this unit low-pressure air (about 7 psi.) from the aerator air header is applied to a closed drum. Regardless of the liquid level in the drum or the drum's placement, the pressure or head on the petcock will remain nearly constant, assuring a fairly uniform rate of feed unless the petcock is readjust-

ed or the viscosity of the defoamant undergoes a marked change.

This type of feeder is excellent for surface application to one or more points through short runs of tubing and for injection into the suction side of spray system pumps.

Proportioning feeders have many advantages over both those previously described. Usually they are easily adjusted and the rate of feed can be accurately controlled for greater economy. These feeders have high working heads, making it possible to apply the defoamant (a) through long runs of small-diameter tubing discharging at desired points, (b) into the return sludge lines, and (c) into the water spray system to supplement the sprays. The high working head also permits an indoor installation for both the feeder and the storage tanks.

A multiple feeder unit driven by one motor and fed from one tank makes for a compact unit. Such a unit may have up to four feeders, each independently adjusted. The use of this multiple feeder permits introduction of a defoamant into any combination of up to four aerators, aerator passes, or water spray headers.

The foregoing indicates that an effective defoamant must have at least four characteristics; namely, easy application, a specific gravity less than that of water, water insolubility, good "knockdown." The liquid foam answers the first requirement because it can be applied with various devices and at many points. Both the specific gravity and the water insolubility were previously discussed.

Good knockdown is necessary for control. A simple field check for it can be made by emptying 4 to 8 ounces into a foaming aerator and then watching its effect on the foam for a few minutes. A marked decrease in foam volume indicates good knockdown quality.

In addition to a good initial knockdown, a satisfactory defoamant must have the capacity to maintain its "foam killing" characteristic throughout the length of the aerator. This residual effect or persistency was noticed in several of the defoamants tested during the last five years. In fact, it was evident to such an extent that effective control usually existed in both the aerated (mixed) liquor and return sludge channels.

The latter may come as a suprise to many, but the condition is readily explained. Practically all of the solids or floc particles come in contact with the defoamant during aeration. Much of the defoamant adhering to these particles in the aerator will remain with them during the subsequent sedimentation and be carried to the return sludge channel. There the concentration of solids is very high and the quantity of defoamant adhering to them is usually enough to effect control.

The adherence of the defoamant is also indicated in the regularity with which small oil slicks keep appearing on the final tank surfaces. These are the minute quantities of defoamant freeing themselves from the solids and rising to the surface.

Experience indicates that, in addition to the characteristics already outlined, a defoamant also should have a low pour point, a low and nearly constant viscosity, and stability of formulation.

The pour point becomes very important in areas subjected to low temperatures where the defoamant applicator is set up and the material is applied outdoors. Because the atmospheric temperature exerts no apparent effect on foam production, it is necessary that the defoamant flow satisfactorily even at abnormally low temperatures for the particular area.

Another flow characteristic, viscosity, also plays a very important role. First, it is important because the head loss is a function of the viscosity. Also, a low viscosity fluid can be more easily controlled, particularly where small heads are involved such as with a drip can; it is also more pumpable.

A second aspect that must be considered in a defoamant's viscosity is the relative increase for a decrease in temperature. The smaller the increase in viscosity as the temperature changes from the operating high to the abnormal lows, the more it approaches the desired constant viscosity. The closer a defoamant approaches the ideal of this characteristic, the more nearly a constant rate of feed can be had for a fixed setting and head. It also would permit storing the defoamant outdoors without requiring warming prior to use. Such a quality also would eliminate the concern caused by the day-to-night temperature drops. Unfortunately, the viscosity of some of the defoamants now in use undergoes a marked change as the temperature approaches and drops below the freezing point.

The remaining characteristic, stability of formulation, ensures both a uniform distribution of the additives in the defoamant during its application and that these additives will not settle out during storage.

Water Sprays

Use of water sprays, usually flat and fan-shaped, has been of considerable help in beating down and controlling foam. Both coarse droplets and adequate water pressure (20 to 40 psi.) at the nozzles are required for a spray system to be effective.

Water sprays are not completely satisfactory because foaming can not be effectively controlled during the low flow periods when foam production is greatest. Ineffective control also is experienced on many occasions when the flow is high. It is believed that excessive foaming under high flow conditions is due to synergism brought about by a change in sewage characteristics.

During periods of excessive foaming the sprays can be supplemented with a defoamant for adequate control. This defoamant can be injected directly into the spray header or headers, or into the aerator passes requiring control, or into the suction side of the pumps supplying the spray water.

Summary

It is quite apparent that there is a correlation between foaming or frothing in aeration tanks and the introduction of synthetic detergents for popular use.

Vigorous agitation is required for frothing or foaming.

Syndets cause more grease to remain in suspension and interfere with sedimentation. These result in a marked increase in the air ratio, requiring increased agitation in aerators, thus increasing the foam production.

Aeration tank foaming with its resultant ill effects can be controlled. It requires one or a combination of the following:

1. Increasing the aeration tank solids level.
2. Applying a defoamant.
3. Using water sprays.

An effective and economical defoamant must have the following characteristics:

1. A liquid.
2. Specific gravity less than water.
3. Water insolubility.
4. Good knockdown.
5. Residual effect; that is, maintenance of the knockdown characteristic throughout the aeration period.
6. Low pour point.
7. Low and nearly constant viscosity.
8. Stable formulation.
9. Low performance cost.

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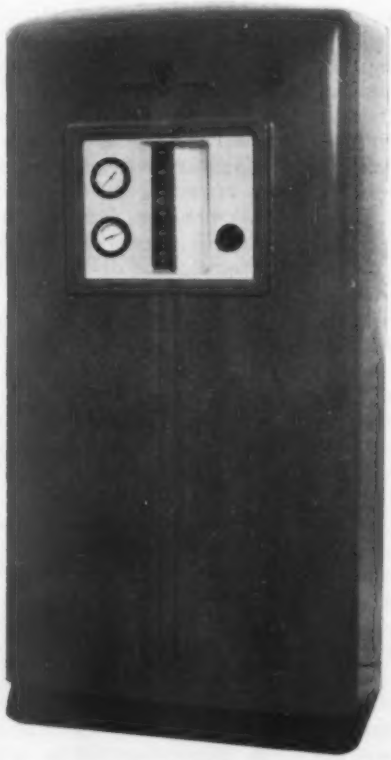
DISINFECTION OF SEWAGE

The need for sewage disinfection cannot be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



W&T Series A-721 V-notch Chlorinator

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

EQUIPMENT

For every sewage plant, there is W&T Equipment to fit. V-notch Chlorinators with capacities from ounces to 8,000 pounds per day—Hypochlorinators and Direct Feed Chlorinators for small plants—and Diaphragm Pumps and Chemical Feeders to meet many varied chemical treating applications. All W&T apparatus is backed by over thirty years' experience.

TECHNICAL INFORMATION

W&T representatives will gladly discuss any sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent on request.

For details circle 582 on inquiry card

NOTES ON SEWAGE CHLORINATION*

IN SEWAGE treatment, disinfection is practiced to destroy pathogenic bacteria and to reduce the total number of bacteria. Chlorine (sometimes calcium hypochlorite) is the usual disinfecting agent, but chlorine is also used for other purposes in sewage treatment. The containers in which chlorine is purchased and the chlorine feeders used are the same as used for water chlorination.

Purposes of Sewage Chlorination

Disinfection is the most important purpose of chlorination in sewage treatment, principally to prevent nuisance and to protect water supplies, bathing beaches and fishing areas.

Other important uses of chlorination in sewage treatment include: *Putrefaction and odor control* by the use of sub-residual amounts of chlorine to prevent early decomposition of the organic matter or to combine with hydrogen sulfide and other odors already formed.

Reduction of B.O.D. to the extent of approximately 2 ppm for each ppm of chlorine added.

Control of corrosion by reducing the hydrogen sulfide content of sewage.

Grease removal by the addition of chlorine and air.

Improved trickling filter operation from chlorination which reduces odors from the filter, reduces ponding, and controls the growth of filter flies.

Bulking control in activated sludge by adding chlorine to the return sludge in an amount calculated according to the formula:

lb Cl_2 per 24 hr = 0.0000834 × S.I. × F × W, where S.I. is Sludge Index (Mohlman) F is mgd of return sludge and W is ppm of suspended solids in return sludge.

Sludge thickening in the activated sludge process by maintaining a residual of 1 ppm in the supernatant liquor layer of the sludge thickening tank.

Digester foaming control by adding chlorine in sufficient amounts to the raw sewage. The amount required depends on local conditions.

Re-use of sewage effluents is possible only when chlorination for disinfection is practiced.

*These notes were adopted from B-I-F Industries Keep Sheet No. 15 by permission.

Types of Chlorination

Whereas water chlorination may be practiced to produce either a combined or free residual chlorine, sewage chlorination involves the production of a combined residual. In some instances a sub-residual is used. Although the process is really combined chlorination it is usually termed simply, chlorination.

Points of Application

Application points for sewage chlorination include:

Upsewer chlorination where chlorine is added before to sewage before it reaches the treatment plant. This practice is usually for the purpose of keeping the sewage fresh and preventing odors.

Prechlorination is the addition of chlorine at the entrance to the sewage treatment plant or ahead of primary treatment units.

Post-chlorination is the addition of chlorine to sewage after some other treatment process, usually primary or secondary treatment. Chlorine is usually added ahead of a contact tank or final settling tank or final long outfall.

Chlorination Capacity

The amount of chlorine used in a sewage treatment plant is expressed in terms of pounds per day and chlorine feeders are calibrated in units of lb per day. The amount of chlorine required depends on the desired result, the chlorine demand in ppm, the flow in mgd, the amount of residual desired, in ppm and contact time.

Chlorine demand depends on the amount and kinds of chemical substances in sewage which will react with chlorine as well as on time of contact and temperature. Chlorine demand is defined as the difference between the amount of chlorine added and the amount of the residual after a specified time. Residual chlorine is that chlorine which will react with ortho-tolidine.

The amount of chlorine required will vary for different sewages, different times of the day, different days of the week and different seasons. It is usually determined on the basis of a 15 minute contact time, but some states require 20 minutes contact.

One set of standards of design requires a capacity available to produce a residual of 2 ppm after 15 minutes, or enough capacity to dose raw sewage with 25 ppm, or primary effluent with 20 ppm, or trickling filter effluent with 15 ppm or activated sludge effluent with 8 ppm.

Control

The feeder capacity required can be calculated from the required dosage multiplied by the factor 8.34 and by the flow in mgd.

As with chlorine feeders used for water chlorination, the types of control available include manual, semi-automatic (step) programmed control, and automatic proportional control, wherein the equipment adjusts automatically to maintain a preset dosage regardless of the change in flow of sewage. The types of feeders available are the same as those described under water chlorination.

Installation

Chlorine feeders for sewage chlorination should be installed according to certain principles. The point of application should produce quick and thorough mixing and sufficient contact time for the treatment desired. The equipment must be accessible to the operator both for normal operation and for maintenance. The space allowed for the chlorine feeders must be sufficient to allow storage of containers and ease of operation and control. Safety factors must be given full consideration in any chlorine feeder installation.

Operation

Inasmuch as the chlorine demand of a sewage changes markedly throughout the day, it is highly desirable to control the dosage rate accordingly or chlorine added may be wasted, either as an excess or as an insufficient amount to produce the desired disinfection. Where laboratory facilities are available, frequent determinations of chlorine demand and concurrent changes in chlorine dosage rates should be made. Many plants make a study of the chlorine demand curve and determine a pattern of dosage rates. The minimum number of changes made in dosage rates should be three a day. Changes every hour or every two hours is more productive of efficient chlorination. Programmed control is highly effective for this purpose.

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Stop the cost and nuisance of storing huge amounts of Chlorine. Buy only what you need—whether it's several carloads, just part of one tank car, or as little as 16 lbs.!

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You save searching time, too, because you have a *single* convenient and dependable source for *all* your Chlorine products—liquid Chlorine, Calcium Hypochlorite, and Sodium Hypochlorite.

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Chlorination Control Nomogram*

THIS NOMOGRAM for chlorination control has been developed primarily to aid in determining the proper setting of chlorine gas feeders for use in the treatment of water, sewage and industrial wastes, and control of slime in cooling, process and white water systems. However, most dry and liquid chemical feed calculations involve consideration of the same factors applicable to chlorine feed, hence, it is apparent the nomogram has broad use and application.

Directions for use of the nomogram are given on the other side of this Keep Sheet. Attention is called to the fact that this "multiple" nomogram is applicable to all conditions, if the user properly employs the factors of 10, 100, 1000, etc., where necessary, and properly places the decimal point when the calculation is completed.

Applications

1. Design Work

For determining the maximum capacity of chlorination equipment needed—If the chlorine requirement of the liquid to be treated is known (or if some value is set as maximum requirement in ppm by a governmental agency), and if the maximum expected flow is known or can be estimated, the nomogram affords a simple means of determining maximum feed rate required.

2. In Operation and Control

As an aid in setting chlorine feed rates in water and sewage chlorinating stations — Having established by chemical tests the chlorine dosage required to effect a desired residual, the nomogram may be employed to determine the proper chlorine feeder setting to produce that residual at any given flow rate.

3. In Plant Performance

To accurately and quickly convert accumulated "known" data into average performance and to readily transpose momentary feed and flow rates to dosage in ppm—From the flow measuring device, accumulated flows over a selected period or momentary flow may be determined. Chlorine flow totalizers or loss in weight measurements of containers on scales provide accumulated feed information and chlorine recorders or the chlorine feeder indicates momentary feed rate in lb per 24 hr. With these data applied to Lines C and A, the chlorine dosage in ppm may be read on Line B.

Examples of Use

1. *Direct Reading*—For a flow of 0.8 mgd (556 gpm) with a chlorine requirement of 1.1 ppm, place straight-edge on 0.8 on Line A and on 1.1 on Line B. (Note that angle with Line B is approximately a right angle and therefore is satisfactory). Read value of 7.35 on Line C. Setting for chlorine feeder is 7.35 lb per 24 hr.

2. *Single Multiplier*—Where the straight-edge nearly parallels Line B—For a flow of 0.2 mgd (139 gpm) with a chlorine requirement of 0.1 ppm, place straight-edge on 0.2 on Line A and on 0.1 on Line B. Note that the angle of the straight-edge with Line B is far from a right angle. Therefore, for more accurate results, place straight-edge on 0.2 on Line A and on 1.0 on Line B and read value of 1.67 on Line C. Multiply this value by 0.1. Setting for chlorine feeder is .167 lb per 24 hr.

3. *Single Multiplier*—Where straight-edge does not cross Line C.—For a flow of 0.7 mgd with a chlorine requirement of 2.5 ppm, note that the straight-edge does not cross Line C. Therefore place straight-edge on 0.7 on Line A and on 0.25 on Line B. Read value of 1.45 on Line C. Multiply this value by 10. Setting for chlorine feeder is 14.5 lb per 24 hr.

Note: Straight-edge approaches right angle with Line B for this placement and is therefore more accurate than using 0.07 on Line A and 2.5 on Line B, which would give the same value on Line C at 1.45.

4. *Single Multiplier* — For normal placement of straight-edge.—For a flow of 7.0 mgd with a chlorine requirement of 0.6 ppm, place straight-edge on 0.7 on Line A and on 0.6 on Line B. Read value of 3.5 on Line C. Multiply this value by factor of 10. (Factor of 10 introduced on Line A.) Setting for chlorine feeder is 35 lb per 24 hr.

The procedure would be the same for a flow of 70 mgd or 700 mgd, etc., using multiplier factors of 100, 1000, etc.

5. *Double Multipliers*—For conditions where factors are introduced in both Lines A and B.—For a flow of 1.7 mgd with a chlorine requirement of 8.0 ppm, place straight-edge on 0.17 on Line A and on 0.8 on Line B. (Note, if straight-edge were placed on 8.0 on Line B, it would not cross Line C.) Read value of 1.13 on Line C. Multiply this value by 100 (factor of 10 on Line A times factor of 10 on Line B.) Setting for chlorine feeder is 113 lb per 24 hr.

The same procedure would be followed for a flow of 17 mgd with a chlorine requirement of 13 ppm, in which case the straight-edge would be placed on 0.17 on Line A and on 1.3 on Line B. The value on Line C of 1.84 would then be multiplied by 1000 (factor of 100 on Line A times factor of 10 on Line B).

6. *Determination of Dosage*—From recorded flow rate and chlorine feed rate—For a flow of 0.63 mgd and a chlorine feed rate of 5.8 lb per 24 hr, place the straight-edge on 0.63 on Line A and on 5.8 on Line C. Read value of 1.1 on Line B. Chlorine dosage is 1.1 ppm.

This operation may also be used for values of flow and chlorine used, greater than the values on Lines A and C, by introducing the proper factors of 10, 100, etc.

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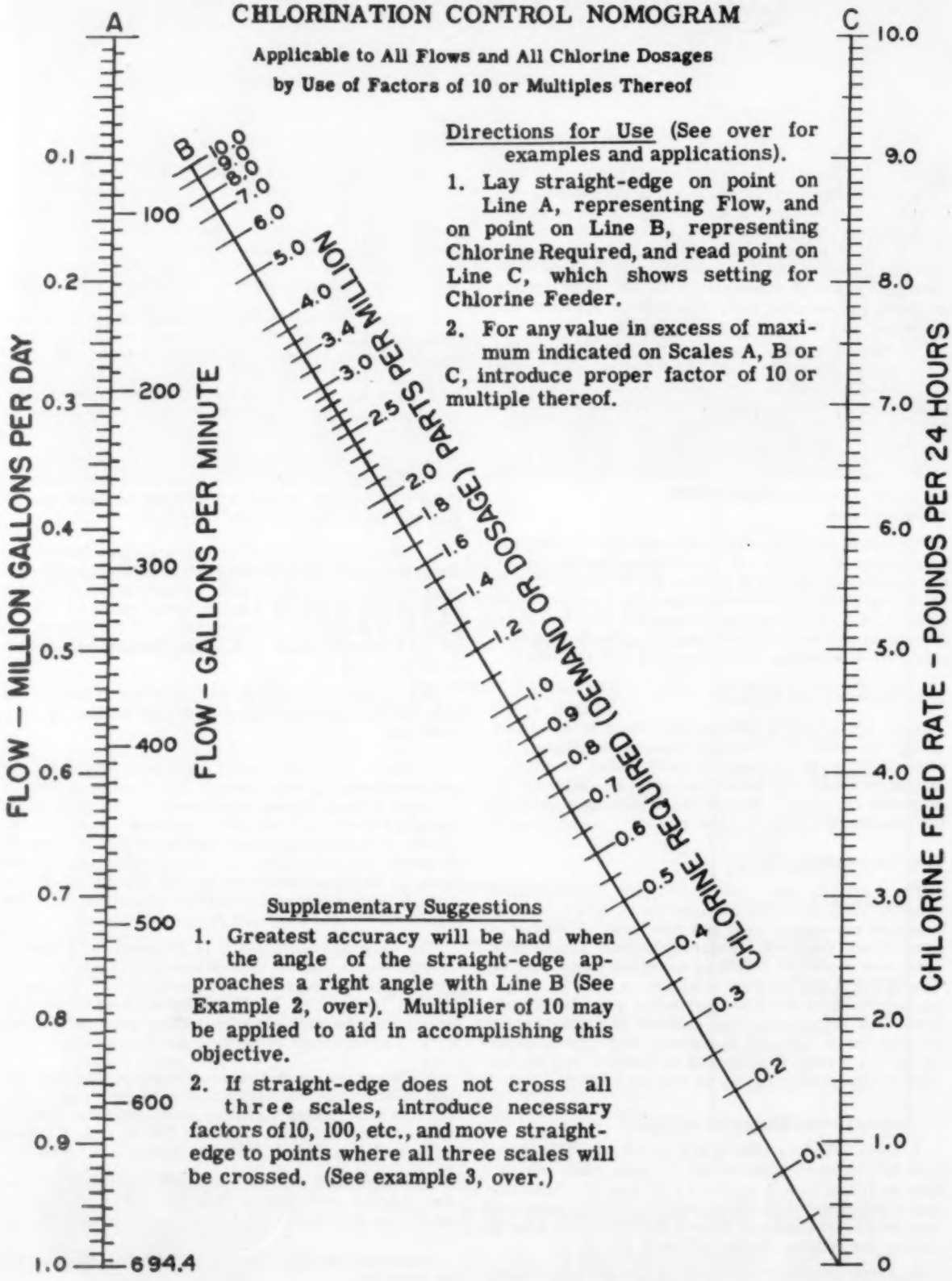
*Reprinted from Keep Sheet No. 21, of B-I-F Industries, Inc., by permission.

CHLORINATION CONTROL NOMOGRAM

Applicable to All Flows and All Chlorine Dosages by Use of Factors of 10 or Multiples Thereof



Directions for Use (See over for examples and applications).

1. Lay straight-edge on point on Line A, representing Flow, and on point on Line B, representing Chlorine Required, and read point on Line C, which shows setting for Chlorine Feeder.
2. For any value in excess of maximum indicated on Scales A, B or C, introduce proper factor of 10 or multiple thereof.

Supplementary Suggestions

1. Greatest accuracy will be had when the angle of the straight-edge approaches a right angle with Line B (See Example 2, over). Multiplier of 10 may be applied to aid in accomplishing this objective.
2. If straight-edge does not cross all three scales, introduce necessary factors of 10, 100, etc., and move straight-edge to points where all three scales will be crossed. (See example 3, over.)

SLUDGE DISPOSAL

THAT MATTER which settles from sewage (except grit) is termed sludge. Raw sludge results from primary treatment, secondary sludge comes from final clarifiers.

The two sludges are entirely different in characteristics (and trickling filter humus differs somewhat from activated sludge). Regardless of source, these solids cannot be disposed of without some treatment or nuisance will result. Treatment of sludge may consist of digestion, dewatering and drying and/or incineration. In some instances dewatering, drying and/or incineration take place without digestion. Secondary sludge when dried makes an excellent soil conditioner (or fertilizer); digested sludge is less desirable for this purpose and raw sludge should not be used on the soil.

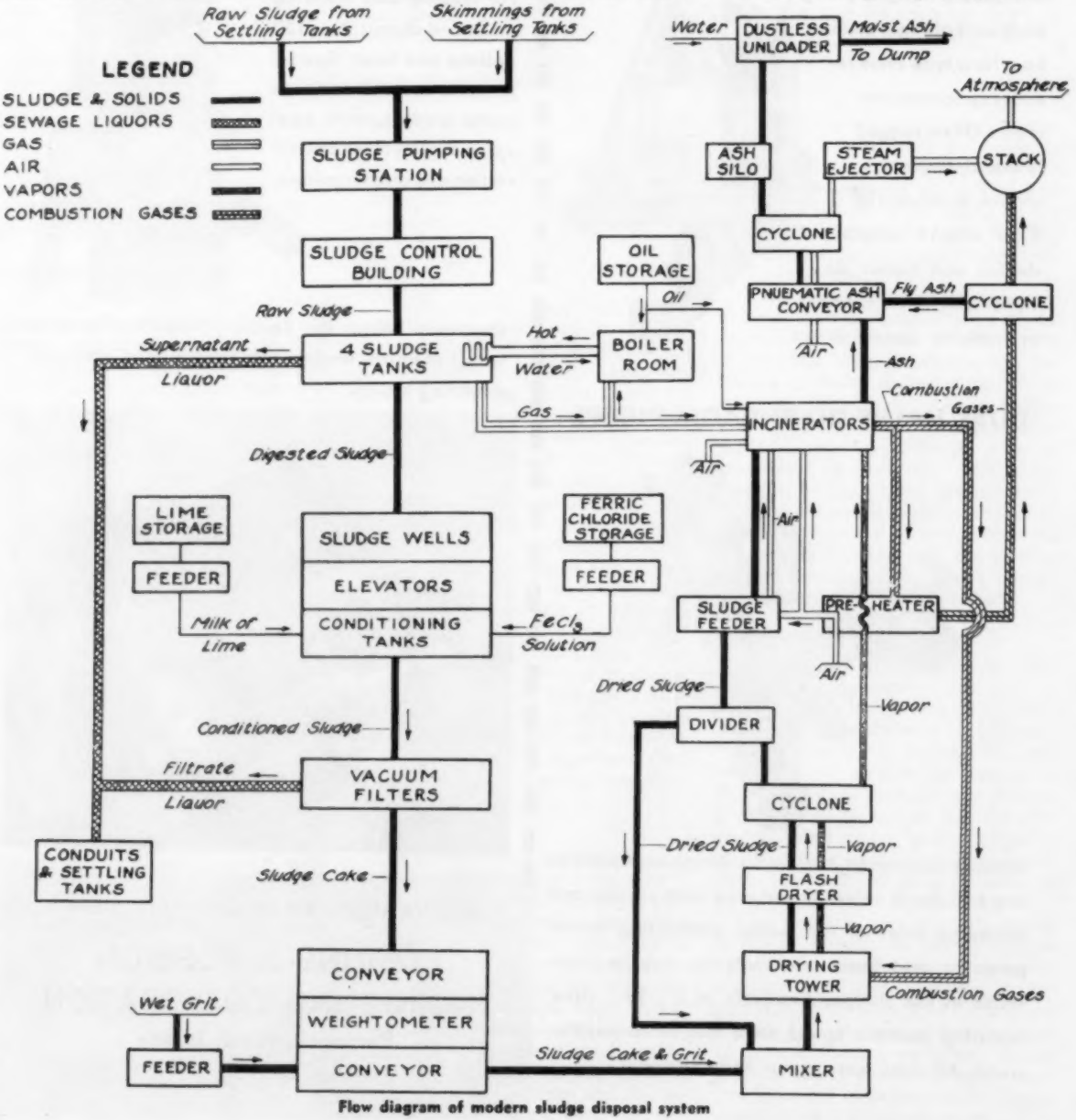
Digestion of sludge is an anaerobic bacterial decomposition, that is, it takes place in the absence of atmospheric oxygen.

Since all sludges contain water, some more than others, one of the methods of sludge treatment is to reduce that water content. Included in the methods of accomplishing this result are the processes of sludge thickening, draining on sand beds, vacuum filtration and biological flotation.

Dewatered sludge may be dried in the open air on sand beds, or mechanically in furnaces designed especially for that use. The former process is termed natural drying.

Where disposal areas and facilities are not available for either wet or dried sludge, it may be burned in an incinerator. The resultant ash must be disposed.

The accompanying diagram shows a modern sludge disposal system.

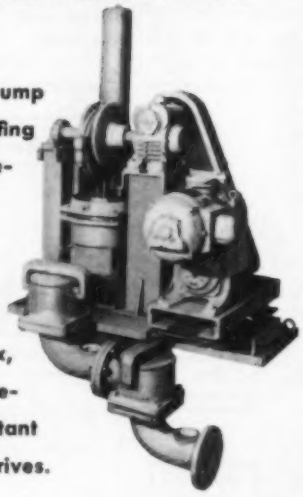


Flow diagram of modern sludge disposal system

KOMLINE-SANDERSON

Sludge Pumps and Chemical Feeders

DUAL VALVE PLUNGER PUMPS



Incorporate integral pump body and plunger stuffing box. New type drive reduces space requirements. Offers rugged low-maintenance service. Available in 7", 9" and 11" simplex, duplex and triplex designs, with either constant or variable speed drives.

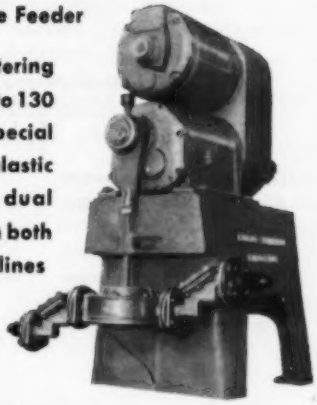
DUAL VALVE DIAPHRAGM PUMPS

Komline-Sanderson dual-valve design incorporates two ball check valves in series on both suction and discharge sides of the pump, eliminating erratic pumping and inaccurate metering due to large solids in the sludge. Available in 2", 2½" sizes, featuring variable speed drive and three-position crank. All sizes have pump body cleanout.

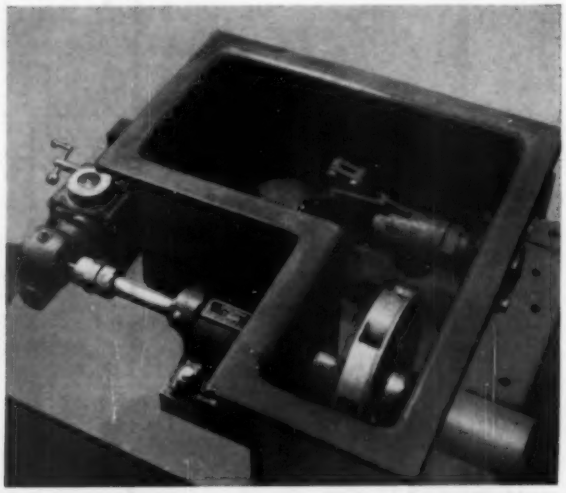
CHEMICAL FEEDERS

Ferric Chloride Feeder

For feeding and metering acids and chemicals to 130 gallons per hour. Special pressure-molded kralastic pump bodies, with dual valve check valves on both suction and discharge lines



Illustrated below; the Komline-Sanderson rotating wheel chemical feeder, with rubber lined tank and Hastelloy wheel.



MECHANICAL EQUIPMENT DIVISION

KOMLINE-SANDERSON ENGINEERING CORPORATION

Peapack, New Jersey

For details circle 584 on inquiry card

SLUDGE HANDLING*

THE DISPOSAL of sludge is a major problem in a sewage treatment plant. Facilities for handling sludge add to the cost of construction and operation. Problems peculiar to the handling of sludge vary according to the type of sludge being handled.

Raw sludge from primary treatment plants contains from 5 to 8 per cent solids of heterogeneous nature including coarse particles, fibrous material, grease, fine sand, trash and ground screenings (where screenings are comminuted.) Activated sludge and trickling filter sludge is relatively homogeneous, with less than 3 per cent solids and presents few hydraulic or mechanical problems in handling; trickling filter humus is similar.

Screenings and Skimmings

Problems of handling ground screenings can be reduced by using screens with openings of ¾ to 1 in. and discharging the ground screenings ahead of the screens. Coarse material leaving the grinder is caught again and reground.

Skimmings consist of all types of flotable material which will rise in a sedimentation tank. This material is frequently skimmed off to wells from which it is pumped to digesters along with the raw sludge. A major percentage of this heterogeneous material is grease which includes fats, waxes, soap and oils. In addition to these substances, skimmings also contain sticks, matches, leaves, paper, feces, soap, rags, hair, and other miscellaneous objects.

In some plants, skimmings have been sold for their grease content but this practice is not generally economically feasible. In other installations, skimmings are burned in special incinerators. Where skimmings are transferred to digestion tanks with raw sludge, the resulting problems include pumping difficulties, clogged lines and meters and scum formation in digesters.

Pumping difficulties result from the congealed character of the skimmings and their resistance to flow. This problem is overcome to some extent by introducing excess water with the skimmings in the well and ahead of the pump suction. Sludge lines handling skimmings become reduced in size and may even clog entirely due to the deposition of the grease on the inside surface of the lines.

Metering of skimmings is difficult because of the tendency of the material to deposit on the inside surfaces of the measuring devices and to clog the throat of differential producers.

Pumping Sludge

Pumps employed for raw sludge may be positive displacement piston pumps or "screw-feed" centrifugal pumps or a combination grinder and centrifugal pump. Clogless centrifugal pumps have come into use in recent years.

The choice of pump will usually consider factors of location, type of sludge, suction and discharge head, etc. Generally, raw sludge pumps are placed in pumping stations below the water level in the sedimentation tanks and therefore operate under a positive suction head. Provision must be made for a build up of pressure resulting from depositions in the discharge line. Thus rugged equipment is required. It is always desirable to have a minimum length suction pipe and as few bends as possible in the suction line.

Maintenance on sludge pumping equipment is high, wear on packing is rapid. This is especially true where the sewage comes from a combined system and contains fine grit (80 to 100 mesh). Cleanliness is a problem in sludge pumping stations caused by leaking packing, cleaning obstructions from pumps, and drawing samples.

Piping

The sizing of pipe for sludge pump discharge lines presents a problem in sludge handling. Some designers prefer small pipes to produce high scour velocities and prevent deposition in the pipe line; others prefer large pipes which give low velocities with low head loss. These pipe lines should have as few bends as possible and cleanout holes at elbows are desirable.

Where skimmings are pumped through raw sludge lines and deposition of grease occurs, cleaning may be done by steam injection to heat the water in the lines. For cast iron pipe this heating (and cooling) must be slow and controlled to prevent cracking. Temperatures of 150 to 180 deg F are desirable. The use of steel pipe for sludge lines is warranted where steam cleaning is to be used and it has been suggested that twin lines be installed so that interruption to pumping can be avoided during cleaning operations.

Metering

Because of the nature of the material being metered, and the tendency to clog, the metering device should be the simplest possible. A Venturi tube especially designed for handling the sludge and with continuous flushing systems for the pressure connections is the most practical.

Some designers do not include metering devices in sludge lines, first because of the difficulties of keeping the device clean and secondly because the nature of sludge makes it difficult to measure rate of flow. Other designers believe that a measurement of sludge pumping discharge, even if inaccurate, is desirable. It indicates whether or not pumps are operating or plugged, and it gives some indication of the amount of sludge removed in the settling tank and the loading on the digestion tanks. Both factors are important to good operation.

Miscellaneous Problems

Sampling of sludge presents difficulties, yet is essential to control of loadings on digesters as well as determining the effectiveness of sedimentation. In order to control the concentration of sludge discharged to digesters, it is necessary to sample frequently to make sure that the concentration of sludge being pumped is at the desired level. This control prevents the costly pumping of volumes of cold water into digesters.

The handling of secondary sludge is not as difficult as raw sludge; it presents few problems of pumping or clogging of lines. Sampling is required in order to control the amount of free water pumped with the sludge. In some instances, secondary sludge is thickened to reduce its water content before it is discharged to digesters or other disposal processes.

* Material for these notes was obtained from "Problems in Sludge Handling" by C. R. Velzy—*Wat. & Sew. Wks.*, Ref. & Data issue, Apr. 1948.

Sludge Digestion

by DON E. BLOODGOOD

Professor of Sanitary Engineering at Purdue University, Lafayette, Ind.

ALMOST EVERY sewage treatment plant in the world applies the process of anaerobic decomposition in the disposal of organic solids. Buswell[1] has written a summary about the use of fermentations in waste treatment. He states that there have been many points of controversy and that even when he wrote in 1954 they had not all been settled.

Methane Fermentation

The anaerobic decomposition of organic solids such as those found in sewage is sometimes called *methane fermentation* because the largest portion of the end product gases is methane. The other gas formed is mostly carbon dioxide. In many fermentations it is quite necessary to provide a pure culture of some microorganism in order to accomplish the desired end. This situation is not true in the methane fermentation of organic solids. In this process it is quite apparent that a mixed culture is at work in the anaerobic decomposition of sewage solids.

In fact, a mixed culture may be necessary in order to convert complex organic solids into methane. This statement is partially proven by observation of nature at work in those places where organics are allowed to accumulate and there is an absence of oxygen. It seems that almost spontaneously decomposition sets in. Not being believers in the miraculous, it must then be concluded that there must be methane-producing organisms widely scattered in nature.

There is considerable difficulty experienced when a bacteriologist attempts to isolate methane organisms so the study of them in pure culture has been limited. It is now believed that besides being methane producers these organisms are non-motile, nonspore forming and Gram negative. They have the ability to use ammonia as a source of nitrogen. It has been observed that they grow at a relatively slow rate, sometimes requiring several weeks to develop into an active culture. These organisms are not necessarily the ones that decompose the complex organic solids in sewage sludge.

Studies have been made to determine what takes place in the decomposition process when sewage solids are disintegrated and the reports indicate that volatile acids are first formed. Acetic, butyric, propionic and valeric acids have been isolated from digesting mixtures. It has been indicated by many writers that it is the decomposition of the volatile acids that results in the formation of the methane and carbon dioxide that make up the major portion of the gas from sludge digestion tanks. Teletzke and Rohlich[2] have reported on a method for determining the concentration of the various acids. They used a chromatographic method for separation and identification of the acids.

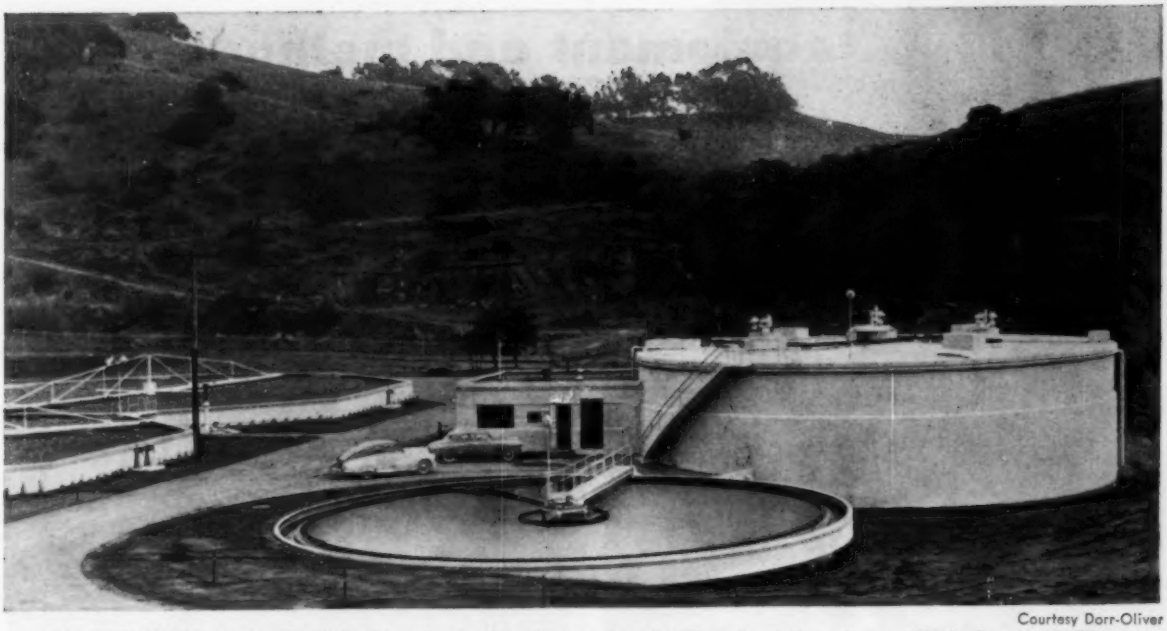
The ratio of carbon dioxide produced to the quantity of methane depends upon the elemental constituents of the compound being used by the bacteria as food. Symons and Buswell[3] stated that for compounds containing carbon, hydrogen and oxygen the general reaction in the methane fermentation can be predicted according to the Equation 1. C is carbon, H is hydrogen, O is oxygen and the subscript letters are for the number of atoms of the respective substances. Symons says, "If water, carbon dioxide, and methane are the only substances involved in the reaction besides the substrate, then their coefficients may be determined algebraically in terms of the numbers of atoms in the substrate molecule. The equation may also be developed in a stepwise manner, the first step being an oxidation-reduction by water to give carbon dioxide and hydrogen, and the second a combination of the hydrogen with part of the carbon dioxide to form methane and water.

This equation gives a simple method for writing the balanced reaction for that portion of the substance that is converted to methane and carbon dioxide. This equation not only defines the gas ratios but also the weight of the gases produced."

Symons and Buswell[3] also report a still more general equation that applies when more complex materials are decomposed. See Equation 2

$$C_nH_aO_b + \left(n - \frac{a}{4} - \frac{b}{2}\right) H_2O \rightarrow \left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4}\right) CO_2 + \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4}\right) CH_4 \quad (1)$$

$$C_nH_aO_bN_cS_dM_{ev} + \left(n - \frac{a}{4} - \frac{b}{2} + \frac{7c}{4} + \frac{d}{2} + \frac{3ev}{4}\right) H_2O \rightarrow$$
$$\left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4} - \frac{5c}{8} + \frac{d}{4} - \frac{9ev}{8}\right) CO_2 + \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8} - \frac{d}{4} + \frac{ev}{8}\right) CH_4$$
$$+ cNH_4HCO_3 + dH_2S + eM(HCO_3)_v \quad (2)$$



Courtesy Dorr-Oliver

BIO-FILTRATION plant with 80-ft dia. primary digesters equipped with recirculating mixers.—Marin County, Calif.

where C is carbon, H is hydrogen, O is oxygen, N is nitrogen, S is sulphur, M is any metal ion, v the valence of M and a, b, c, d, and e, the number of atoms present.

Both of these equations show that there is a very definite relationship between the pounds of organic solids destroyed and the volume and weight of gas produced. The weight of gas produced is usually greater than the pounds of solids destroyed because some water is used in the process and therefore the hydrogen and oxygen from the water make up part of the methane and carbon dioxide.

Temperature

Digestion of sewage solids has been accomplished at different temperatures. It has been found by practical experience that digestion does not take place at temperatures around 39° F. It can be assumed that when solids are placed in a tank that is maintained at near that temperature it is much like preserving materials in a refrigerator. A tank used to store solids at low temperatures will, when warmed, attempt to digest all of the organic matter in a short period of time. The results are usually disastrous.

The work of Fair and Moore[4] gives some idea about the rates of digestion at different temperatures. Their experiments were conducted using Imhoff sludge collected at Fitchburg, Mass. and seeded with sludges that remained from previous tests at particular temperatures. The "time of digestion" was obtained by recording the number of days required to produce a quantity of gas equal to 90 per cent of the total produced at 59°F. The data collected by Fair and Moore is presented in Table 1. It seems very possible that the time of digestion at the different temperatures given by them, may be considerably higher than the time of digestion required in modern digestion tanks because modern tanks are fed continuously and a maximum number of active organisms is probably present at all times. In the studies reported there may have been a delay of several days before the organisms reached their maximum activity. The quantity of gas produced (90 per cent of the ultimate) was 7.65 cu ft per lb of fresh volatile solids added. The information given by Fair and Moore is, however, an excellent guide to those who need to know the effect of temperature on sludge digestion.

TABLE 1

Time Required to Digest Sludge at Various Temperatures (By Fair and Moore)[4]

Temperature °F.	Time of Digestion Days
59	67.8
68	46.6
77	37.5
86	33.3
95	23.7
104	22.7
113	14.4
122	8.9
140	12.6

Quality of Gas Produced and Per Cent Digestion

All of the solids added to a digestion tank are not decomposed, in fact, all of the volatile solids are not de-

TABLE 2

Volatile Solids in Raw and Digested Sludges

City	Type of Plant	% Volatile in Dry Sludge Raw	Digested
Gary, Indiana[5]	Activated Sludge	52.4	46.0
Toledo, Ohio[6]	Primary	66.1	43.1
Jackson, Mich.[7]	Activated Sludge	58.0	42.0
Racine, Wis.[8]	Primary	57.4	38.2
Fort Wayne, Ind.[9]	Activated Sludge	56.0	40.0
Average		57.9	41.9

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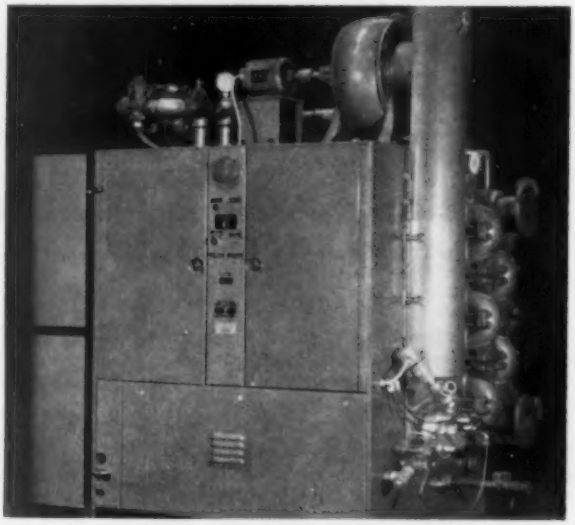

Digester Heaters and Heat Exchangers—External heaters for digestion tanks allow complete accessibility in a compact unit of high thermal efficiency. Raw sludge or a mixture of raw and recirculated digester contents is heated as it passes through the unit. With external heating, the problems of heating coils within the tanks (caking, corrosion) are avoided. Cleaning and maintenance are simplified. Detailed drawings and estimated digester heating loads furnished on request. Submit the number of digesters, tank capacities and quantity of raw sludge.

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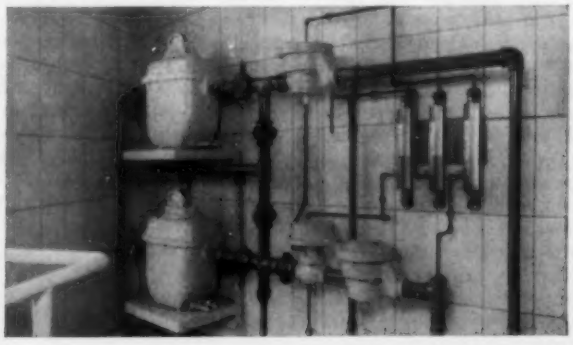

Gas Safety Equipment—A number of devices, each designed to perform its function in a gas utilization system with the greatest possible protection against explosive or burning mixtures of sludge gas and air: flame traps, pressure reliefs, pressure reliefs combined with flame traps, flame cells, waste gas burners, drip taps, accumulators and manometers.

For details circle 585 on inquiry card

Kraus Interchange Process —A process of aerating waste activated sludge, utilizing the digester supernatant liquor to produce highly nitrified solids that: (1) During *normal* loads, produce sludge that settles more readily to provide greater purification. (2) During *peak* loads, provide a reserve of highly nitrified active solids which balance the increased load of organic matter. A truly "controlled" activated sludge process.

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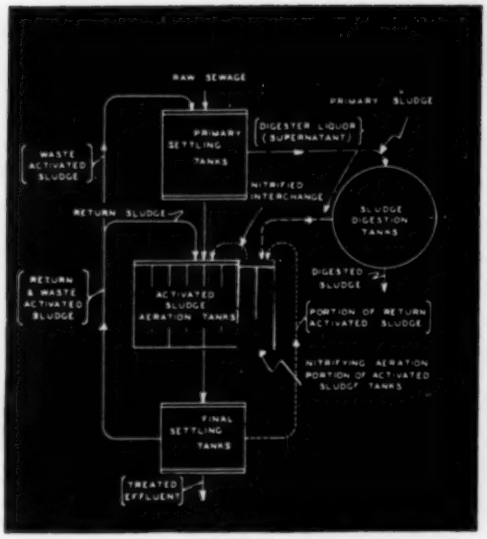
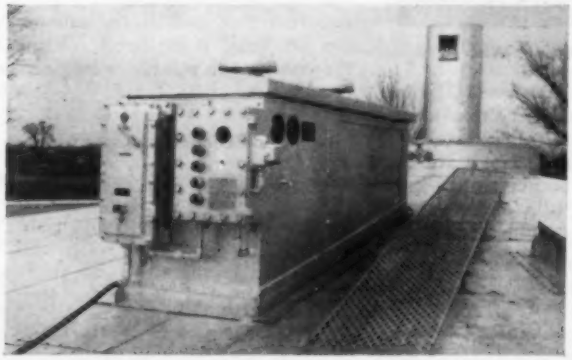
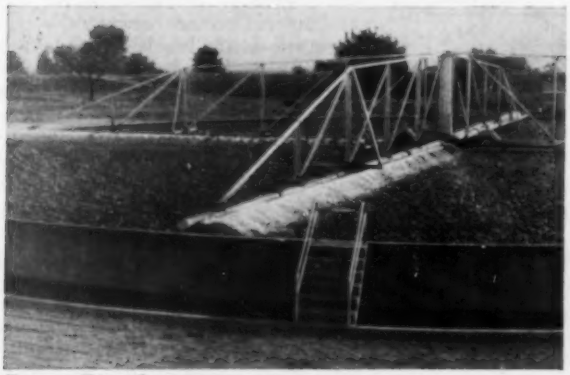




Pearth Gas Recirculation System —An effective method of increasing dispersion and digestion of scum, allowing full effective use of total digester volume at all times. Designed as an integral part of the PFT Floating Cover, the Pearth system breaks up the scum and releases entrained gas by recirculating digester gas and discharging below the scum level. Complete data on the Pearth Gas system on request. Submit digester volume, diameter and number of digestion tanks.



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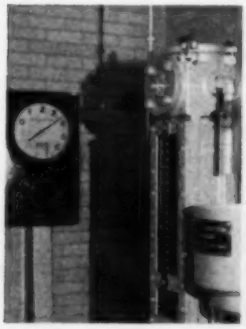

Digester Accessories —The PFT Supernatant Selector, Gauge, Sight Glass and Sampler units provide automatic withdrawal of the best digester liquor at a slow, continuous rate. The PFT Cover Position Indicator reflects the slightest Floating Cover movement on a large dial in the Control Room, showing digester liquid level at a glance.

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SLUDGE DIGESTION is established practice at Green Bay, Wis.

composed. It has been estimated that about half of the volatile solids are converted to gas in digestion. The average data from five midwestern cities, presented in Table 2 shows the volatile solids content in raw and digested sludge to be 57.9 per cent and 41.9 per cent.

These data indicate that in 2000 pounds of raw solids there are 1158 pounds of volatile solids (2000 x 0.579) and 842 pounds of ash (2000 —1158). In the digested sludge there are 842 pounds of ash that is 58.1 per cent of the digested sludge (100.0 per cent—41.9 per cent). The total solids in the digested sludge amount to 1449 pounds (842÷0.581). There are 607 pounds of volatile solids in the digested sludge (1449—842). Originally there were 1158 pounds of volatile solids in the raw sludge and after digestion there are only 607 pounds, which means that 551 pounds or 47.5 per cent would have been destroyed in digestion or (551 x 100÷1158), i.e., the per cent digestion is 47.5.

It has been pointed out that there is a relation between the pounds of volatile destroyed and the volume of gas produced. It would, therefore, seem advisable to have reported the quantity of gas produced per unit of volatile solids destroyed. Most of the reporting however, is on the basis of cubic feet of gas per pound of volatile solids added. The quantity of gas produced, by this more common way of reporting, is between 6 and 8 cubic feet per pound of volatile solids as shown in the data presented in Table 3.

TABLE 3
Gas Production from Volatile Solids

City	Cu Ft of Gas Per Lb Volatile Solids Added	Cu Ft of Gas Per Lb Volatile Solids Digested
Fort Wayne, Ind.[9]	7.2	15.1
Racine, Wis.[8]	5.8	10.7
Jackson, Mich.[7]	5.4	11.3
Richmond, Ind.[10]	7.6	—
Aurora, Ill.[11]	6.0	11.3
Average	6.4	12.1

It appears that the quantity of volatile solids in a raw sludge may not necessarily indicate the amount of gas that can be produced from it but it is apparent that usually the amount of gas produced is in direct relation to the amount of volatile solids decomposed.

Heating of Digestion Tanks

To maintain a satisfactory temperature in a digestion tank it is necessary to supply heat to compensate for that lost through the walls and to raise the temperature of the raw sludge being fed, up to the temperature being maintained in the digestion tank. The amount of heat lost through the tank walls depends upon the degree of insulation of the tank and the difference between the temperature on the inside and outside of the tank.

Babbitt[12] says that the heat lost from a tank in a day can be calculated by the formula

$$H = 24A_t\ (T_i - T_e)\ (C_1)$$

Where

H = Btu lost from a tank per day.

A_t = surface area of the tank, top, bottom and sides in square feet.

T_i = temperature, degrees Fahrenheit inside the tank.

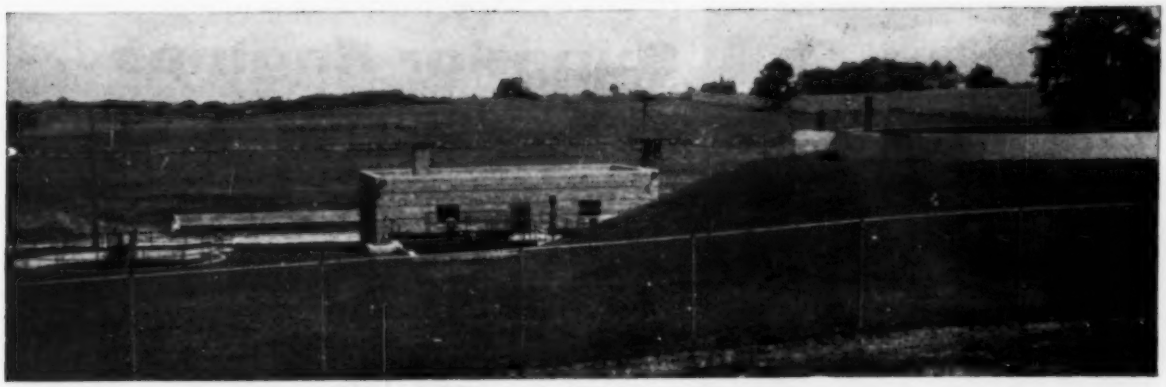
T_e = temperature degrees Fahrenheit, outside the tank.

C_1 = coefficient of thermal conductivity in Btu per hour per square foot of tank surface per degree (Fahrenheit) difference in temperature.

The coefficient C_1 has been said to be 0.07 for concrete entirely covered with dry earth, 0.10 for a concrete with the top exposed to air and surrounded by dry earth, and 0.20 to 0.25 for a concrete tank with the top exposed to air, the sides covered with moist earth and the bottom in ground water.

A concrete tank 30 feet in diameter and 20 feet deep with earth banked to the top is perhaps representative of a small installation. Computations for the heat loss from this tank would be:

GAS HOLDER at Sheboygan, Wis. plant



DIGESTER at right—New Holstein, Wis.

Area of top = $30^2 \times \pi \div 4 =$ 706 sq ft
Area of bottom = $30^2 \times \pi \div 4 =$ 706 sq ft
Area of sides = $30 \times \pi \times 20 =$ 1884 sq ft
Total area = 3296 sq ft
Operating temperature of tank = 90°F.
Outside temperature, mean for Mid-West = 52°F.
Coefficient of thermal conductivity = 0.10
$H = 24 \times 3296 \times 38 \times 0.10 = 300{,}595$ Btu

The heat value of sewage gas is 585[11] to 646[13] Btu per cu ft and the amount of gas required to keep the 30 ft diameter tank warm would be approximately

$$300{,}595 \div 646 = 465 \text{ cu ft.}$$

This digestion tank has a volume of 12,708 cu ft and when operated under an average loading of 3500 persons (3.62 cu ft per cap.) it might be expected to produce 2200 cu ft per day if the gas production is about average. (Average at Racine, Wis. for 1951-55 was 639 cu ft per cap. per day[8]). It takes about 21 per cent of the gas produced to keep the digestion tank up to temperature. On a cold winter day the gas required would be as much as 50 per cent of the total produced.

Babbitt[12] has also presented a formula for the calculation of the heat required to raise the temperature of the incoming sludge to that of the sludge in the digestion tank. The formula is:

$$H = W(T_t - T_s)(S)$$

In this formula H is the Btu required to raise the daily sludge addition to the temperature of the sludge in the digestion tank; W is the weight of sludge entering the tank; T_t is the temperature of sludge in the tank degrees Fahrenheit; T_s is the temperature of the sludge entering the tank in degrees Fahrenheit; S is the specific heat of sludge which is taken to be equal to 1.0 but actually may be slightly less than this number.

With a sewage flow of 100 gal per capita, 200 ppm of suspended solids and a 50 per cent removal in primary treatment there should be 5820 pounds of sludge with 5 per cent solids concentration produced. The heat required to raise the temperature of this 60°F. sludge to 90°F. would be

$$H = 5820 \quad (90\text{-}60) \times (1) = 174{,}600 \text{ Btu}$$

To supply this number of Btu would take 270 cu ft of gas.

If supernatant is withdrawn heat is removed from the tank and this is also a loss in heat from the tank. This quantity of heat is also 174,600 Btu because this is the amount of heat required to raise an equal weight of sludge entering the tank.

According to these calculations, it would require 1005 cubic feet of gas per day to heat the incoming sludge, to make up for the heat lost through the walls of the tank, and to account for the heat removed from the tank in the supernatant.

This illustration shows that about 45.5 per cent of the gas produced is required to maintain the temperature in a digestion tank of this size. If the temperature in a digestion tank cannot be maintained with the gas being produced an operator can determine the volume of gas that can reasonably be expected by use of the formula.

$$G = 5.3312 \text{ VAB}$$

where

G = cubic feet gas per day
V = volume of sludge in gallons
A = solids concentration of sludge (%)
B = Vol. solids, % of dry solids

$$5.3312 = \frac{8.34 \times 6.4}{100 \times 100} \times \text{cu ft/lb vol. solids added}$$

Summary

1. Methane forming bacteria are known to multiply at a slow rate.
2. Acetic, butyric, propionic and valeric acids are formed in digesting sludge.
3. The ratio of methane to carbon dioxide in sewage gas depends upon the organic constituents of the sludge being digested.
4. There is a definite relation between the amount of solids decomposed and the quantity of gas produced.
5. Temperature of the liquid in a digestion tank controls the rate of decomposition of the sludge.
6. About 50 per cent of the organic matter in raw sludge is converted to gas in sludge digestion.
7. All of the volatile solids in sewage sludge are not decomposed.
8. An adequately fed digestion tank should produce a sufficient amount of gas that when burned should maintain the temperature of the digestion tank above 85°F.

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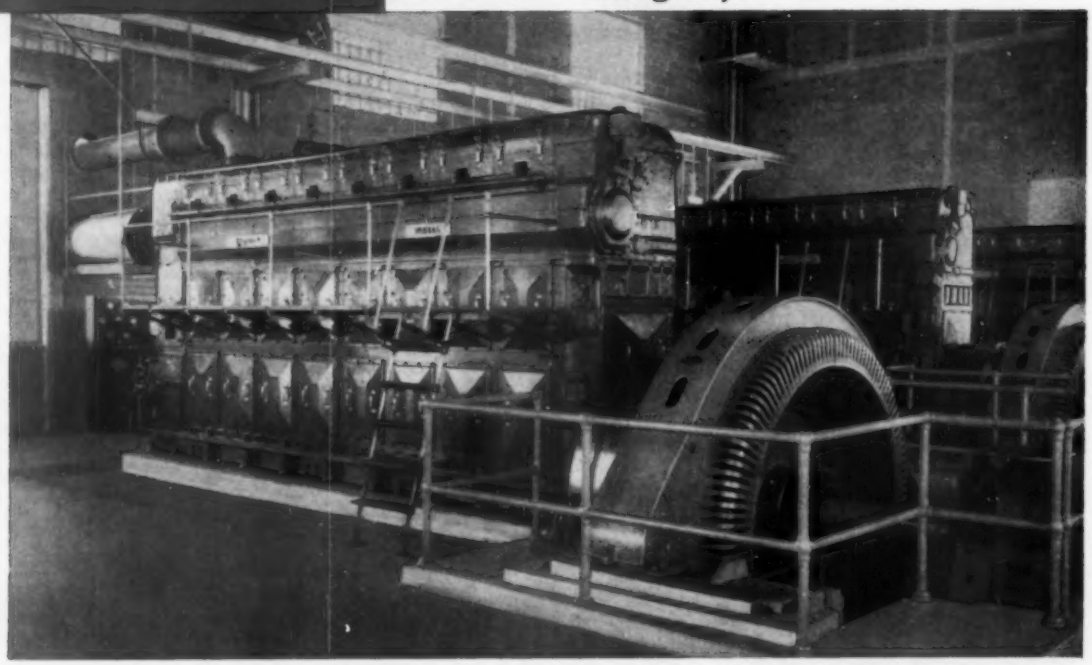

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"CO Alarm" in Digester Operation

by FRANK H. MILLER and W. T. BARRON

Respectively Chief Engineer and Superintendent, Sewage Treatment, Hampton Roads Sanitation District Commission

THE HAMPTON ROADS Sanitation District Commission, serving Norfolk, Virginia, and its environs, operates three primary sewage treatment plants with separate sludge digestion and chlorination. The Lamberts Point Plant, the Army Base Treatment Plant, and The Boat Harbor Treatment Plant at Newport News.

At the Lamberts Point Plant and the Boat Harbor Plant periodic trouble with sudden failure of the digestion process has been experienced. These failures were studied and found to be caused by three factors.

Factor #1—Raw sludge load beyond the capacity of the existing digestion tanks.

Factor #2—Scum buildup in the digestors that resisted all efforts to effect dispersion. (Filter tip cigarettes, among other things, are no help!)

Factor #3—This factor is related to the scum buildup. The H.R.S.D.C. has external heat exchangers for sludge heating in two of their plants and submerged heating coils in the other. The scum buildup seems to restrict the proper dispersion of heat throughout the tanks. On several occasions temperature samples have been taken throughout the entire depth of the tank to find that the upper 10 feet in the tank had a temperature of less than 60°F, while the next lower 12 feet had a temperature of over 90°F. This condition was was much more pronounced in the tanks heated with the external heat exchangers than in the tanks with submerged hot water heating coils; however, loading is much less in the latter. Singly or in combination, these factors contribute to making the digestion process a critical operation that must be watched closely at all times.

Experience a "Dear Teacher"

By bitter and costly experience we learned that when a digestion tank has failed, it has never been possible to bring it back to normal operation again when there is no standby digester capacity to which can be diverted a portion of the daily heavy load of raw sludge. In our case we had no choice but to pump the sludge into the "sick" digesters or shut down the plant. The plants are in such close proximity to oyster beds and bathing beaches that any interruption in the treatment process is highly undesirable. It was also learned that a "sick" digester could not be remedied by the daily addition of seed sludge hauled by tank trucks. In one instance good seed sludge was hauled by tank truck and applied at the rate of 30,000 gallons per 24 hours for a period of one week. At the end of this period there was no laboratory evidence or any other improvement in the digester. It is felt that in the battle of the sick digester, as in war, no matter how large the army, if too few soldiers are put in the field at one time they will be defeated by the enemy. We proved this point by filling our elutriation tanks (110,000 gallons capacity) with good seed sludge, withdrawing 110,000 gallons of sour sludge from the "ailing" digester and replacing it by rapidly pumping in the seed sludge. As a result the digester returned to normal operation.

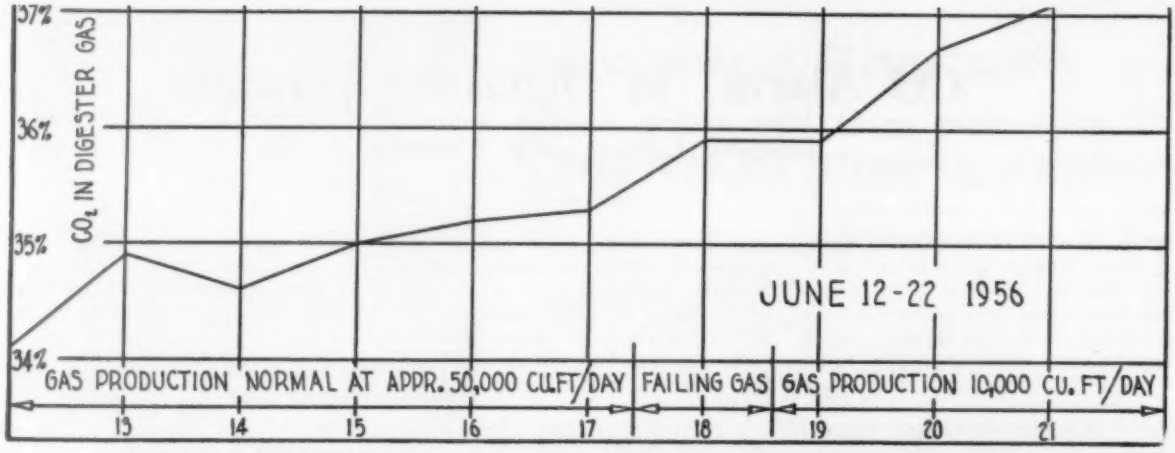
We Search for a Warning Signal

Our interest became critical in some practical method that could be used to indicate impending digester trouble before it is too late. We were sure that by the time a significent pH change takes place in the digester liquor the sludge has lost its buffering power and is "sick". Using the test for volatile acids, it was found that a normal operating digester had a volatile acids content of from 85 to 250 ppm. Samples from the scum layer would run a volatile acids content of from 1,000 to 2,000 ppm. To our sorrow it was found that a digester could have a 250 ppm volatile acids content and forty-eight hours later have a volatile acids content of over 1,000 ppm with an accompanying gas production drop of 60%.

The small quantity of gas still being produced after failure in this instance showed a CO_2 content of between 50% and 60%. A daily CO_2 content check on the gas from this digester was made. As the digester was coaxed back into operation it was observed that the CO_2 content gradually dropped. Over a period of a month the CO_2 content dropped from a high of 60% to a daily average of 33%. When this daily average of 33% was re-established the digester was back in normal operation, producing a

CO_2 GAS ANALYZER permanently located in the digester building near the manometers on gas lines from individual digesters

On left the rapid test for CO_2 content of digester gas is being made for entry on the day-to-day record chart alongside.



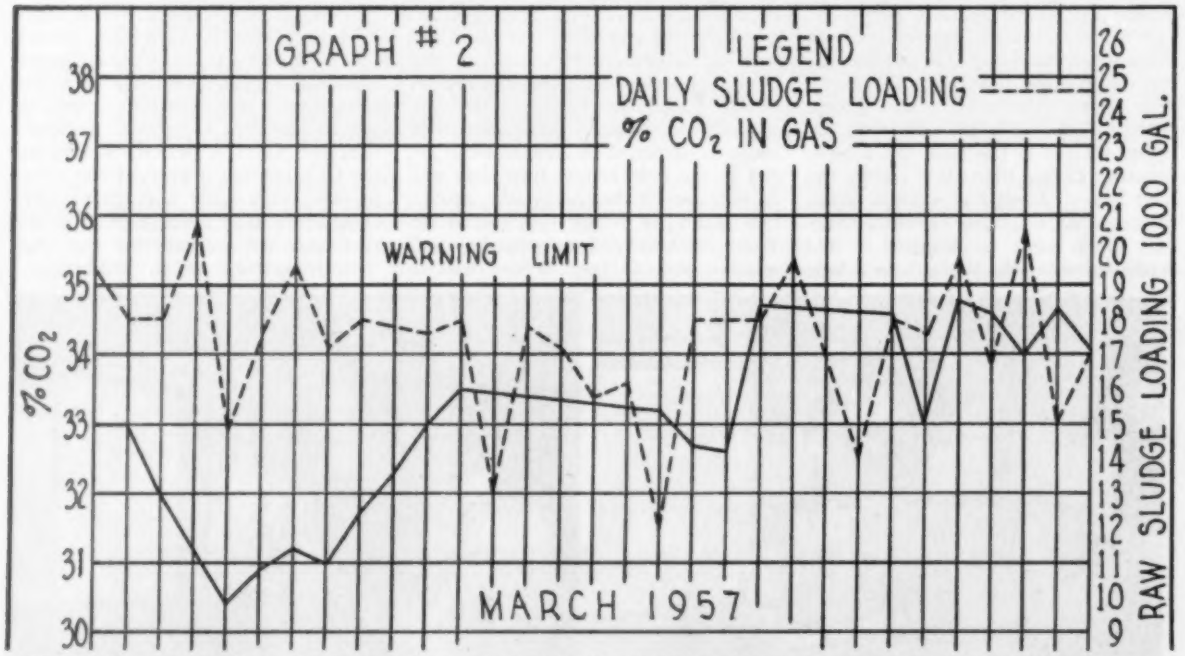
GRAPH #1—Reproduction of a ten day portion of CO_2 record chart at the Boat Harbor Plant

Note the three days of persistant CO_2 increase, June 19-22, the fore-warner of trouble and digester failure that followed.

quantity of gas in proper relation to the daily raw sludge feed.

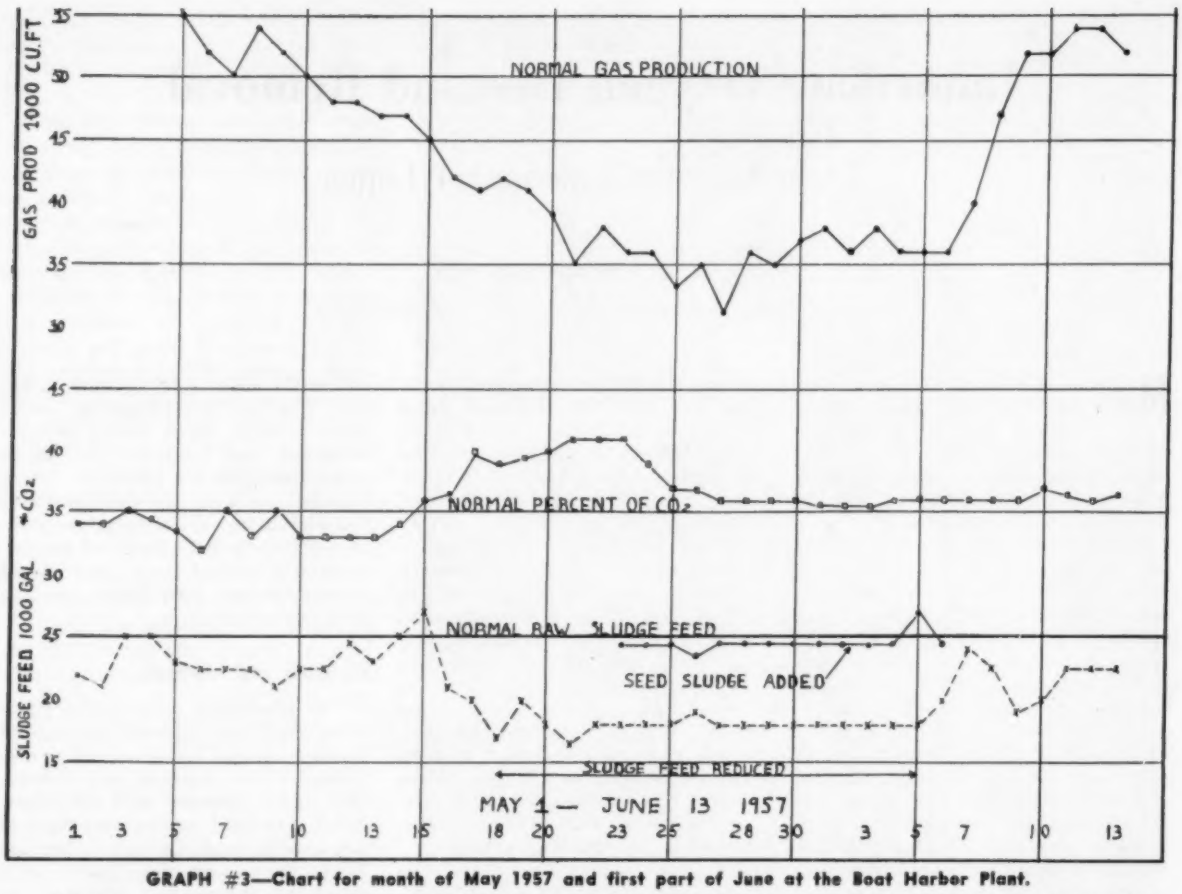
Our records indicate that a digester in normal operation will produce a gas with from 31% to 35% CO_2 content. Of course if lime is being fed to a digester on a routine basis the CO_2 content will be lower. Any plant that feeds lime to its digester as a routine procedure will have to establish what the normal CO_2 content of its gas should be. Our records indicate that when the CO_2 content of the gas builds up to between 36% and 37% trouble will soon follow. On days of exceptionally heavy raw sludge loads the CO_2 content of the gas will go above 35% temporarily, but usually drops back below 35% when the load is reduced. A sudden jump of CO_2 on a daily check can be expected if any abnormal conditions exist.

What to watch for is that presistent upward trend in CO_2 content for three or more days. This is the key to controlling a digester by daily recording the CO_2 content of the gas. We set up a graph in the digester control room with a horizonal red line drawn at 35%. The CO_2 content of the gas from each digester is determined daily at the same time of day and plotted on this graph. Any CO_2 reading of 35% or over on consecutive days is watched very carefully. If the CO_2 increase trend continues the raw sludge load is shifted to another digester if possible, or may even be tank trucked to another plant. The scum and heat situation is also checked. In our opinion the trend of rising CO_2 in digester sludge gas is the best early warning indication of impending digester trouble of any control measure now available, no matter what the cause. This trend can usually be recognized in time to circumvent further trouble. Presented herein are three graphs, two of which represent a portion of the actual plant



GRAPH #2—Reproduction of a 30 day CO_2 record chart for No. 2. Digester functioning normally at the Lamberts Point Plant.

Note the relationship between the digester loading (dashed line) and the fluctuating CO_2 content (solid line), but never exceeding the 35% line for more than one day at a time.



GRAPH #3—Chart for month of May 1957 and first part of June at the Boat Harbor Plant.

Note the warning signal of persistant increase of CO_2 content beginning May 13th and climbing to 41%. The remedy consisted of reduction of digester loading and resultant reduction of CO_2 in gas to the 36% level.

control graph.

Graph #1 shows percent CO_2 during a trouble period, demonstrating the rising CO_2 which was not reflected by either volatile acids in the sludge or total gas produced.

Graph #2 shows CO_2 results in the normally operating digester. Note the relatively smooth CO_2 curve obtained.

Graph #3 records Raw Sludge Feed, Seed Sludge Added, Percent CO_2 and total Gas Production in a composite graph for a recent period of perilously imminent digester failure. In this case, a failing gas production and the CO_2 rise in the gas occurred at about the same time. Perhaps neither alone, and most certainly not the gas production record alone, would have been entirely convincing of the imminence of trouble. Together, their early warning resulted in remedial action and in all probability avoided a much more serious condition than that which did occur. It is to be noted that the CO_2 increase warning began on May 14th and the gradual but presistent rise in CO_2 content for three successive days was a clear warning of trouble ahead unless corrective measures were applied.

In each of our three treatment plants we have installed a standard Orsat type stack gas analysis unit with the burette and the single CO_2 absorption unit only. This equipment cost approximately $130.00 but less expensive gas analyzers for the simple CO_2 determination are available. The absorption unit is charged with 180 ml of 9-N. NaOH, which is replaced when it becomes very milky due to sodium carbonate precipitation. Tests are made daily at the same hour each day on all primary digesters by the regular operating personnel.

Conclusions

By the time a significant change has occurred in pH value in a digester, it is usually too late to save a heavily loaded tank.

Volatile acids content in a digester cannot be determined in any practicable manner with sufficient accuracy and in time to permit needed adjustments which might avoid digester failure.

The rise of CO_2 content in digester gas above the established normal is the best early warning signal of failure yet discovered and usually becomes evident in time to take corrective measures.

The gas analysis check can be made quickly and easily by an operator, with a minimum of special instruction. The services of a chemist are not required to make this daily routine check.

In making CO_2 determinations:

(a)—Place the gas analyzer near the digester gas line in a permanent place. Do not attempt to move it about the plant (equipment is fragile and expensive breakage will otherwise be high).

(b)—Do not use composited gas from more than one digester at a time for testing. Results will be misleading and need will not be served.

(c)—Purge gas line thoroughly with digester gas before drawing gas into testing equipment.

(d)—A convenient point for sampling is usually the centrally located manometer tubes for all digesters. From here gas can be conveyed readily by rubber or plastic tubing to apparatus located nearby.

Immediate Oxygen Demand Removal

From Digester Supernatant Liquor

by H. O. HALVORSON, Ph.D.

Chairman, Department of Bacteriology at the University of Illinois.

MANY OPERATORS have suspected that the supernatant liquor from a digester cuts down the efficiency of secondary treatment. If this be so, it may well be due to a high immediate oxygen demand that robs the flora in the trickling filter and activated sludge plant of oxygen. This can happen because, when a liquid with a high immediate demand bathes the flora, the oxygen in the sewage may be used up faster than it can redissolve. At the best, oxygen is very sparsely soluble in water and the transfer rate into solution may be very low. If the dissolved oxygen is exhausted for moderately short periods of time, aerobic bacteria may die or be retarded in their growth so that secondary treatment ceases to function normally. To avoid this, it is wise to remove this immediate demand before the sewage is given secondary aerobic treatment.

This suspicion became a conviction from some preliminary observations made on the digester operating on the yeast waste at the National Yeast Corp. plant at Crystal Lake, Illinois. It was found that the effluent from the digester had a 5-day B.O.D. of about 1500 ppm and that 300 ppm of this could be satisfied by merely whipping air into the liquid with a Waring blender. From preliminary studies it looked as though the immediate demand in this supernatant liquor was due to sulfides coming either from the organic sulphur or from the reduction of sulfates in the water. In any case, this observation led to the studies reported here involving laboratory and field tests to ascertain whether or not it would be practical to remove this immediate demand before the waste is discharged to secondary treatment.

Research has shown that it is commercially unfeasible and impractical to carry out the oxidation of the chemical and/or auto-oxidizable compounds under atmospheric conditions and in the absence of vigorous agitation. The use of atmospheric conditions requires many hours of pretreatment and, therefore, the use of super-atmospheric pressure is a practical necessity for the success of the operation. With pressure aeration, the immediate dissolved oxygen demand (I.D.O.D.) is satisfied in minutes rather than hours required with normal aeration.

Materials and Methods

The laboratory tests in this study were made on digester supernatant liquors obtained from several plants: Crystal Lake, Rantoul and Urbana, Ill.; and Owatonna and Rochester, Minn. The field studies were made at Bensenville and Crystal Lake, Ill. Some tests were also made on a simulated supernatant obtained by adding sodium sulfide or sulfite to domestic sewage.

For the laboratory studies, the im-

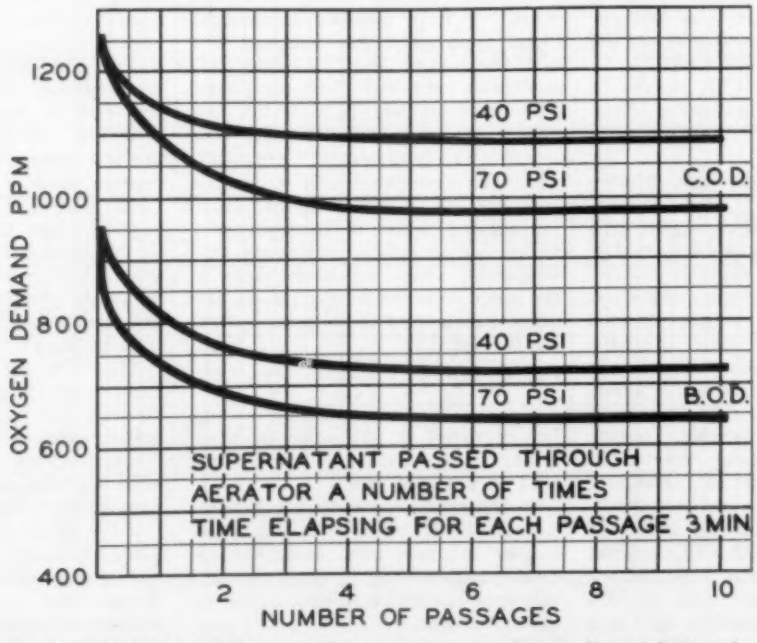


Fig. 1—OXYGEN demand of yeast digester supernatant liquor—No catalyst used.

mediate oxygen demand (I.O.D.) was determined by one of two methods. In one the directions specified in the "Standard Methods of Water and Sewage Analysis" were followed; i. e. a measured amount of the waste is added to diluting water in a B.O.D. bottle. This is allowed to stand 30 minutes, after which the remaining dissolved oxygen is measured in accordance with standard methods. The difference between the content of dissolved oxygen initially and after 30 minutes standing multiplied by the dilution gives the I.O.D. This is referred to later as Method A. In the other method (referred to as Method B) a regular 5-day B.O.D. determination was made on the sample before and after it had been aerated in a Waring blender for 5 minutes. The difference in the B.O.D. before and after aeration was regarded as the I.O.D.

In the analysis that was made in the field, a special pressure aeration unit manufactured by Yeomans Brothers Co. of Melrose Park, Illinois, was used. This device permitted the waste to be aerated in a closed chamber in the presence of air under pressure. The air and waste were mixed as they were pumped into the tank under pressure. After a few minutes' contact in the pressure tank, the liquid was released, after which the excess dissolved gas escaped. The oxygen demand was determined on a sample by the chemical method using the dichromate method (Porges et al; *Sewage & Industrial Wastes;* 22,318—1950). The difference between the oxygen demand before and after the aeration was regarded as the measure of the I.O.D. In this method, as in the laboratory studies, $CuSO_4$ was used as a catalyst to hasten the oxidation of the auto-oxidizable substances.

Experiments at Crystal Lake

It was mentioned, heretofore that some laboratory studies were made on the supernatant obtained from the digester serving the waste treatment plant at the National Yeast Corp. in Crystal Lake, Illinois. In this plant the yeast waste is pretreated by digestion in accordance with the teachings of Buswell. Using Method A, we found that this supernatant had an I.O.D. of 300 ppm with an initial 5-day B.O.D. of 1500 ppm. We also observed a rapid uptake of oxygen with this waste in a Warburg respirometer. Preliminary studies on this waste led us to believe that the I.O.D. here was due to a large extent to sulfides because a removal of the sulfides by precipitation resulted in a marked reduction in the I.O.D.

In the field studies at Crystal Lake, effluent from the digester was aerated under supera-atmospheric pressures with the special pressure aeration unit, mentioned above, and the I.O.D. and B.O.D. were determined on the waste before and after the aeration. The results are shown in Fig. 1.

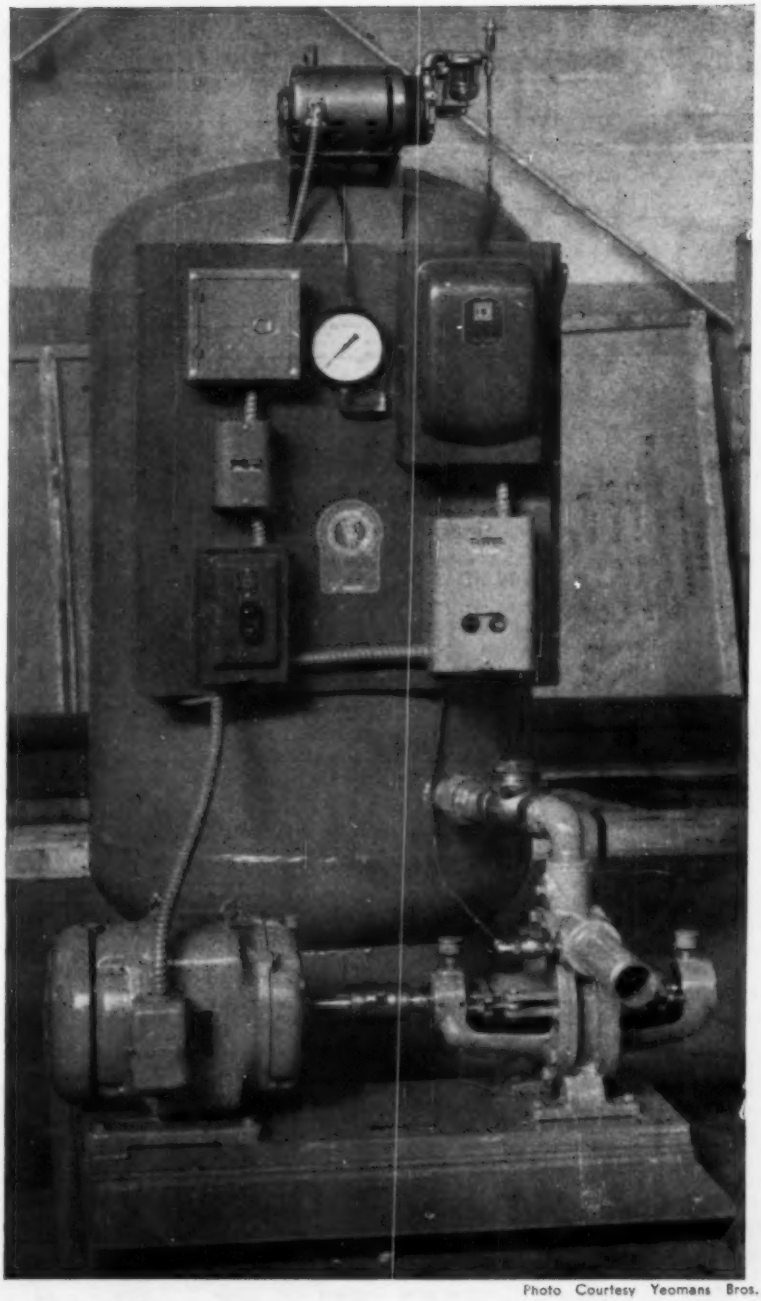


Photo Courtesy Yeomans Bros.

PRESAIRE® Supernatant Corrector used in field studies at Crystal Lake and Bensenville, Ill.

Studies on Simulated Supernatants

Two simulated supernatant liquors were made, one by adding .237 grams of Na_2SO_3 to 100 ml of domestic sewage, and the other by adding .116 grams of Na_2S to 100 ml of sewage. The I.O.D. was determined on each of these by Method A before and after aerating for 5 minutes in a Waring blender. The results are shown in Table 1.

Three samples of simulated supernatants were made by adding to the first .0237 grams, to a second, .0474 grams and to a third, .237 grams of Na_2SO_3 to 100 ml of domestic sewage. Another similar set was prepared but with the addition of 3 ppm of $CuSO_4$ as a catalyst. The I.O.D. was determined on each of these six samples by Method A before and after aerating the samples for 5 minutes in a Waring blender. The results are shown in Table 2.

TABLE 1

Contribution of Sulfite and Sulfide to I.O.D.

Sample Containing	Immediate Oxygen Demand (I.O.D.) Before Aeration	After Aeration	Removed By Aeration
Na_2SO_3	280	230	50
Na_2S	150	96	54

TABLE 2

Effects of Copper Sulphate on the Removal of I.O.D.

Sample	Immediate Oxygen Demand Before Aeration	After Aeration	Removed By Aeration
Without Copper Sulphate			
.0237 gr. Na_2SO_3	29	3.7	25.2
.0474 gr. "	59	31.0	28.0
.237 gr. "	296	237.0	59.0
With Copper Sulphate			
.0237 gr. Na_2SO_3	29	0.0	29.0
.0474 gr. "	59	0.0	59.0
0.237 gr. "	296	5.0	291.0

TABLE 3

I.O.D. of Digested Supernatants

Supernatant	Parts per Million (ppm) B.O.D. Before Aeration	B.O.D. After Aeration*	I.O.D. Removed
Rochester, Minn., No. 1	2620	1420	1200
Rochester, Minn., No. 2	2600	2000	600
Owatonna, Minn.	495	495	0
Rantoul, Ill., No. 1	600	380	220
Rantoul, Ill., No. 2	400	400	0
Rantoul, Ill., No. 3	1090	950	140
Urbana, Ill.	1400	1200	200

*Five minute rapid mechanical aeration

TABLE 4

The Effect of Pressure Aeration on the Removal of the I.O.D. From the Digester Supernatant at Bensenville, Ill.

Date	Aerator Liquor	$CuSO_4$ Added ppm	C.O.D. Demand ppm	Air Input cfm	Flow gpm	Pressure psi
3/29/57	Influent	0	2550			
	Effluent	0	2020	1.2	34	60
	Effluent	1	1680	1.2	34	60
	Effluent	3	1600	1.2	34	60
4/2/57	Influent	0	1950			
	Effluent	0	1850	2.0	34	60
	Effluent	1	1840	2.0	34	60
	Effluent	3	1840	2.0	34	60
4/3/57	Influent	0	2048			
	Effluent	0	2040	1.2	34	60
	Effluent	1	2014	1.2	34	60
4/5/57	Influent	0	2649			
	Effluent	0	2308	1.2	34	60
	Effluent	1	2250	1.2	34	60

Laboratory Studies

On the various digester supernatants that were obtained 3 ppm of $CuSO_4$ was added to each of them as a catalyst and then the I.O.D. was determined by Method B; i. e., the 5-day B.O.D. on these supernatants were determined before and after aeration for 5 minutes with a Waring blender. The results are given in Table 3.

Field Studies

The supernatant from the digester at Bensenville was passed through the Yeoman's pressure aeration unit with and without the addition of $CuSO_4$. The results obtained are given in Table 4.

Discussion

It is obvious from the above that sodium sulfite or sodium sulfide can impart to sewage an I.O.D. which can be removed by adequate aeration. The oxidation of these compounds, however, is relatively slow in the absence of a catalyst and aeration at atmospheric pressures. With the addition of 3 ppm or more of $CuSO_4$ the oxidation becomes fairly rapid, so that the I.O.D. can be satisfied with a relatively short period of aeration. It has been noted that some supernatants had a fairly high I.O.D. while others had none, or at best, a very low demand.

It appeared to the author that this correlated with the odor of hydrogen sulfide coming from these supernatants. Those with the highest demand had a strong odor. It is likely, therefore, that the value of the I.O.D. may depend upon the amount of organic sulphur in the waste or the amount of sulfate in the water that can be reduced to sulfides by the action of anaerobic bacteria.

Of course, organic sulfur, such as in the amino acid cystine, occurs in proteins and urine so no domestic, packing plant, or creamery waste is without it. Hydrogen sulfide is a product of anaerobic decomposition of this material. It is also apparent from the above results that the I.O.D. can be satisfied by aeration preferably under pressure in the presence of small amounts of $CuSO_4$.

DEWATERING, DRYING AND INCINERATION

DIGESTED sludge (and raw sludge, as well as secondary sludge) contains a large amount of free water and in general cannot be disposed of until this free water is removed. (One exception is direct application of liquid digested sludge to farm land.) Therefore, the sludge must be dewatered before the final step in disposal. Dewatering may be accomplished on sand beds, by chemical coagulation and vacuum filtration, lagooning, and, in the case of raw sludge, by flotation through biological activity followed by filtration.

Sand beds or sludge drying beds are level areas of underdrained sand upon which the wet sludge is applied to a depth depending on the kind and character of the sludge. The applied sludge drains and dries with a rapidity depending upon the weather conditions and the character of the sludge. The "dried" sludge reaches a moisture content of 50 to 60 per cent, shrinks about 65 per cent in bulk and is spadable after ten days to three weeks. Freezing and thawing, and rain add to the speed with which water-binding colloids are removed from the sludge and hasten its dewatering, but where adverse winter conditions exist, covering of the beds with glass-roofed "greenhouses" makes it possible to carry on operations all year. The area of sand beds required may vary from about 0.5 to 2.0 sq ft per capita, depending on many factors. Most sand drying beds are used in conjunction with Imhoff tank installations or small plants where mechanical dewatering is too expensive.

Chemical Conditioning

Sludge conditioning or coagulation with chemicals is essential to the effective utilization of vacuum filters as a means of dewatering sludge. Upon the addition of conditioning chemicals, the colloidal matter in the sludge is "shrunk" and its water released so that it may be filtered. For raw, digested and chemical precipitated sludges, the common coagulants are ferric chloride and lime although aluminum chloride, and aluminum sulfates have been used with lime. For digested sludges the chemical consumption averages 2 to 3 per cent ferric chloride and 6 to 10 per cent lime (CaO). Raw sludge requires less chemicals; 1.3 to 1.5 per cent ferric chloride and 3.5 to 4.0 per cent lime. Activated sludges can be conditioned with ferric chloride alone, with 3 to 4 per cent of chemical. (All percentages are based on pounds of dry chemical to pounds of dry sludge solids.)

Elutriation

Elutriation is a process for the "washing" of digested sludge by passing the sludge counter current through a flow of clear water or sewage effluent. In this manner, decomposition products of digestion, particularly ammonium bicarbonate, are washed out of the sludge. Thus the alkalinity of the sludge is reduced and therefore less lime will be required for conditioning since much of the lime used reacts with the bicarbonate alkalinity. Elutriation also removes those chemical products which tend to stabilize the colloidal nature of the sludge. With the removal of these "peptizing" substances, the sludge can be coagulated more easily. The process was originated by A. L. Genter and has been installed at a number of plants throughout the country. Elutriated sludge requires little if any lime and only about 35 per cent as much ferric chloride as unelutriated digested sludge.

Vacuum Filtration

Vacuum Filters generally are drums which rotate on a horizontal axis, partly submerged in a tub of conditioned sludge. The deck of the drum is covered with a wire mesh or other solid covering over which is laid a covering of filter cloth. Wool cloth is used when lime is not used for conditioning, cotton cloth where lime is used. Synthetic cloths are also used. Vacuum is applied inside the drum for about five sixths of its rotation. Sludge particles are sucked against the cloth and form a cake. During rotation the free water is removed from the solids and discharged through a pump to the raw sewage influent. This liquid is clear and relatively free of B.O.D. and amounts to about 80 per cent of the volume of the digested sludge treated.

Before the filter drum completes its revolution the vacuum is cut off and air pressure applied to remove the cake from the filter cloth. A doctor blade is used to help remove the cake. On some filters a string discharge is used in place of air pressure and doctor blade, the strings which lie against the filter cloth for most of the revolution of the drum then leave the drum, after the vacuum is released, and pass over a separate roller at which point the sludge cake is discharged.

A variation of the string vacuum filter is the Komline-Sanderson Coiled Spring Filter. This filter is constructed with stainless steel decking over which two layers of coiled springs (like cords) are laid down in overlapping positions by means of rotating grooved cylinders. Vacuum is applied for 50 per cent of rotation, and the filtrate passes between and through the coils, which discharge over a roller and then are washed before returning to position.

The weight of the sludge cake removed may be determined from any filter by discharging the sludge cake onto a moving conveyor belt fitted with a device for continuously weighing and integrating the weight of the sludge on the moving belt.

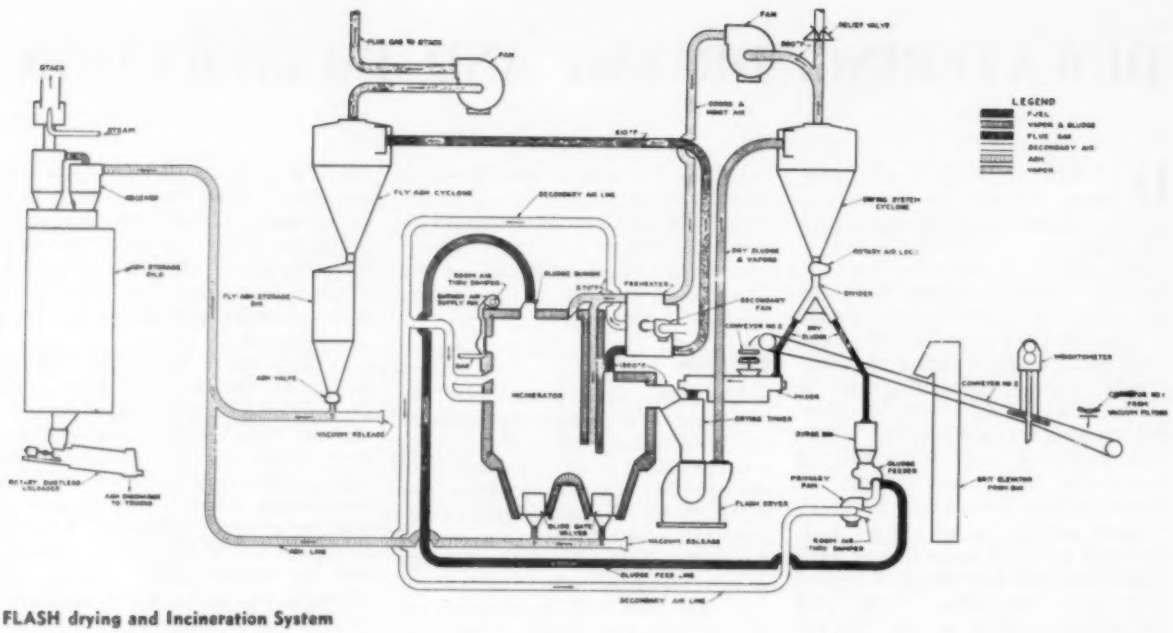
Flotation

Biological flotation is a process for the thickening of raw sludge without chemicals and conditioning it for ease of dewatering on vacuum filters. Experimental work of the Allegheny County Sanitary Authority at Pittsburgh, Pa., before construction of the plant indicated that at 20 to 35 deg. C., a period of approximately five days produced an acid fermentation and the formation of carbon dioxide bubbles which floated sludge solids to the surface of the tank from which they could easily be removed to vacuum filters. Raw primary sedimentation tank sludge of 5 to 8 per cent solids was thus concentrated to a solids concentration of 14 to 20 per cent. Subnatant liquor is clear and can be returned to the raw sewage. The solids are easily filtered to decrease the moisture content.

Drying and Incineration

In small installations, wet sludge cake may be hauled away to a fill, but in large plants, the cake may be dried (and used for fertilizer) or incinerated. Dryers of several types are available: Double-Shell, semi-direct heat, Louisville rotary, rotary louvre, atomizing, and flash dryers.

Incinerators are of two principal



FLASH drying and Incineration System

types, Raymond Flash Dryer system (Combustion Engineering) and the Multiple Hearth system (Nichols-Engineering and Morse-Boulger).

The Flash drying system dries and burns the sludge in a dustless, odorless combination of units, consisting of furnace, flash dryer, wet and dry sludge mixers, heat exchangers, and fly ash collector. Wet sludge cake is mixed with previously dried sludge from the hot gases in a cyclone, some being passed to the furnace where it is incinerated and some to the pug mill for mixing with wet sludge cake.

The multiple hearth incinerator consists of a refractory lined, steel jacketed circular unit containing four or more hearths, one above the other. Alternate hearths have openings at the center and alternate hearths have openings around the periphery. Rotating plows or rabble arms are attached to a hollow air-cooled vertical central motor-drive shaft and the teeth of the rabble arms break up the sludge and move it to the central or peripherial opening. In the Nichols Multiple hearth furnace drying takes place on the upper hearths.

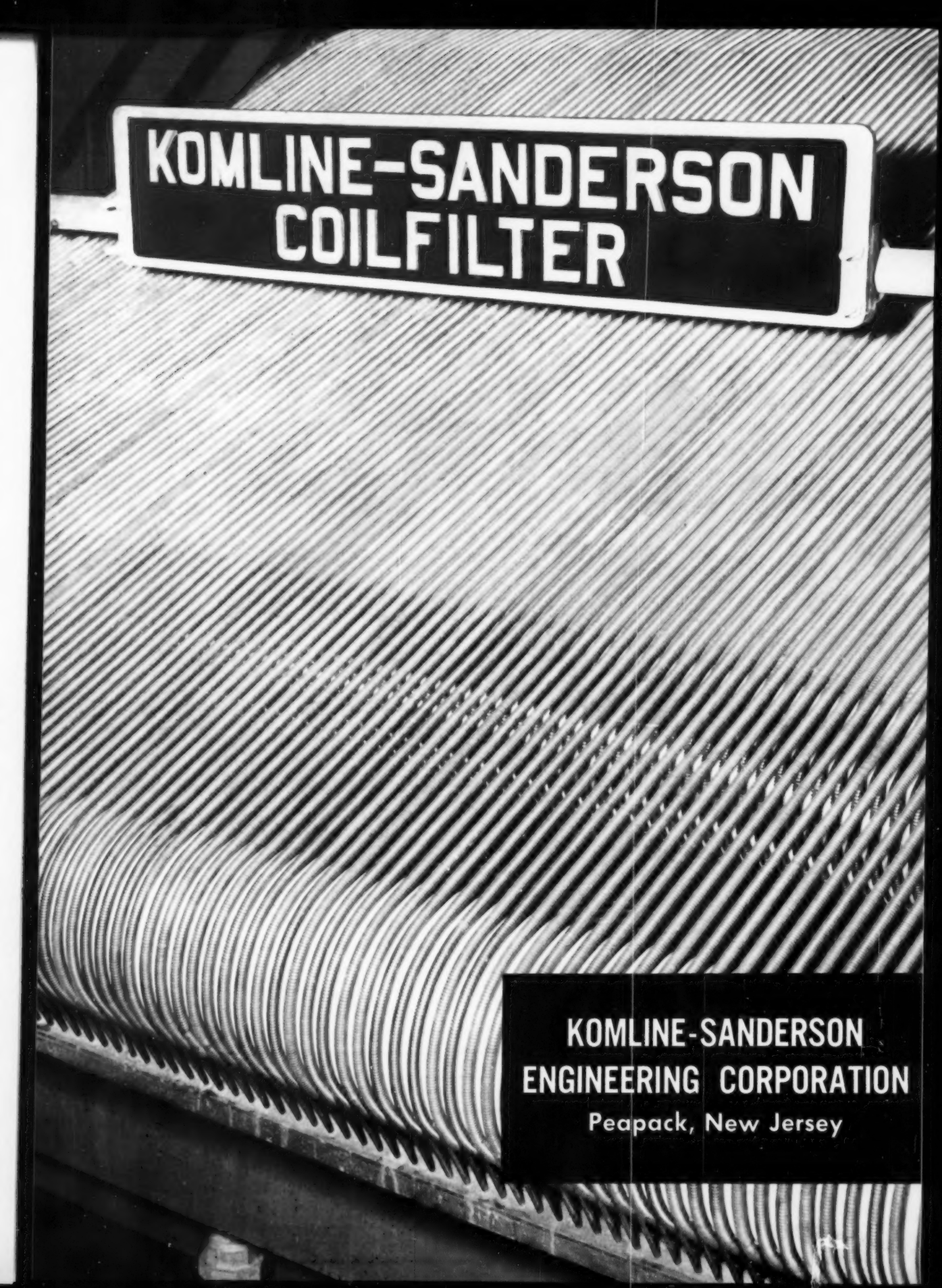
In the "Martin Multizone" furnace (Morse-Boulger Co.) the top hearths are for drying, the middle hearths for incineration, and the bottom hearths for combustion. Vapors from the drying are drawn off and discharged into the combustion zone. In a modification of this furnace, wet sludge is added to the lower zone and is dried by downdraft from the incinerating zone, the dried sludge is then transferred by a conveying system to the top hearths.

This type of furnace has been used to burn thickened raw primary sedimentation sludge containing 85 to 90 per cent moisture. Although the heat value of raw sludge is higher (6000-7000 Btu. per lb.) compared to digested sludge (4000-5000 Btu. per lb.), this type of incineration requires more external heat (to evaporate the water) but it does eliminate the need for chemical sludge conditioning and vacuum filtration and the cost thereof.

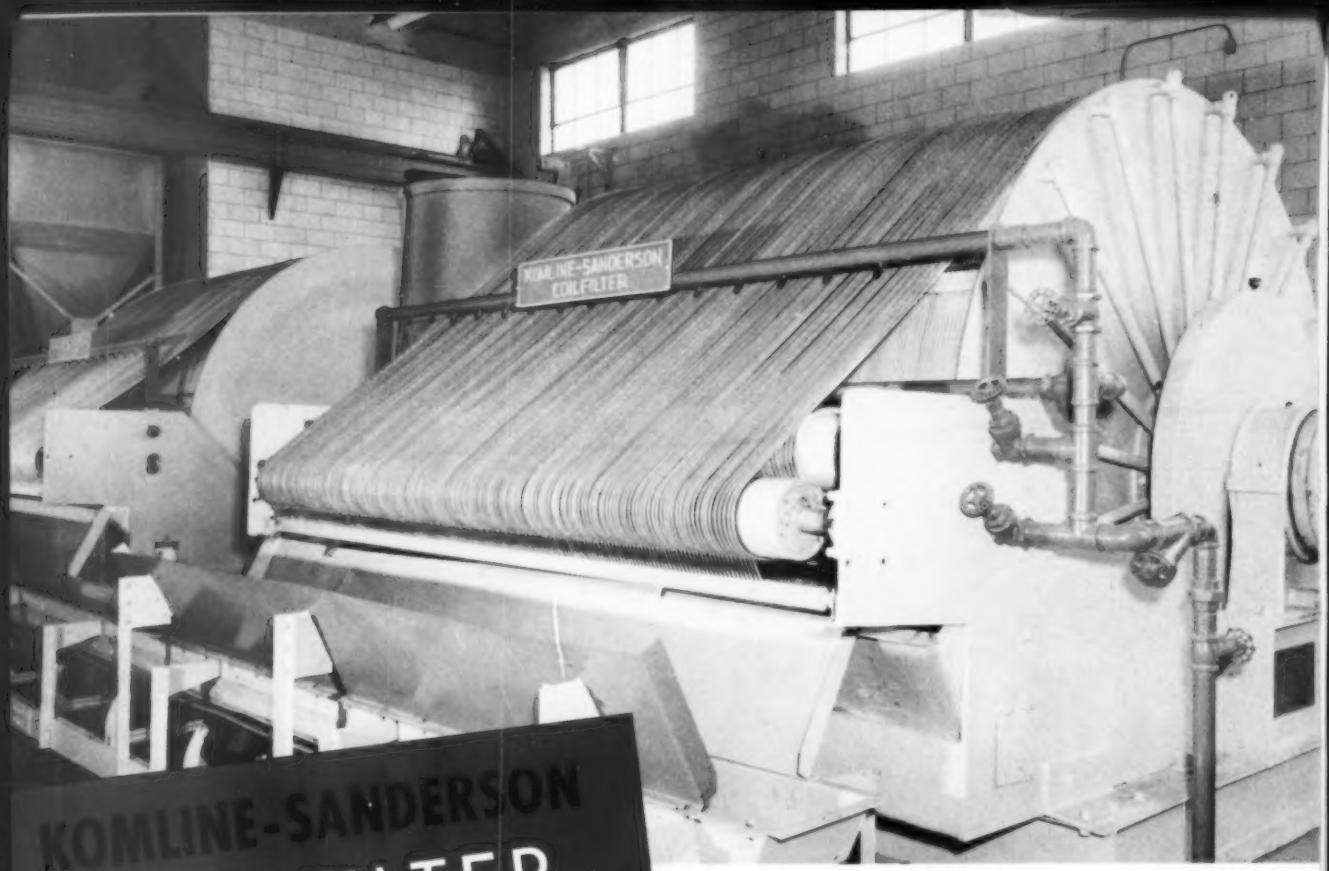
In either type of furnace it is possible to obtain dried sludge or incinerated ash as desired. The ash is inert, finely divided, and can be used as fill. It has no residual nuisance characteristics whatever.

Lagoons

Lagoons, earth diked basins, have been successfully used as open digestion units(deep pit sludge digestion). Odors are relatively absent. Operation produces satisfactory sludge digestion and a clear supernatant liquor that can be discharged to streams. If the beds are used only for digestion, at least 0.17 cu ft is required per pound of solids added or roughly 0.017 cu ft per capita per day. If the lagoons are also used for dewatering as well as digestion, a capacity of 0.4 cu ft is required for each pound of solids added or 0.04 cu ft per capita per day, from which figure it is possible to calculate the approximate number of days required to fill a lagoon of known capacity.



KOMLINE-SANDERSON
ENGINEERING CORPORATION
Peapack, New Jersey



KOMLINE-SANDERSON COILFILTER

FOR DEWATERING FRESH OR DIGESTED SLUDGE

NON-CLOGGING
PERMANENT FILTER MEDIA
CONSTANT OUTPUT
LOW OPERATING COST

The Komline-Sanderson Coilfilter is the *only* performance-proved sludge vacuum filter with permanent-type, self-cleaning filter media. Its operating efficiency is so widely recognized that during the past six years over 90% of all sewage sludge vacuum filters installed in this country have been Coilfilters.

Of all-metal, corrosion-resistant construction, the Coilfilter is a rugged, simple, functional unit that has demonstrated its ability to dewater virtually all types of sewage sludge, at a constant rate, without blinding and at low operating and maintenance cost.

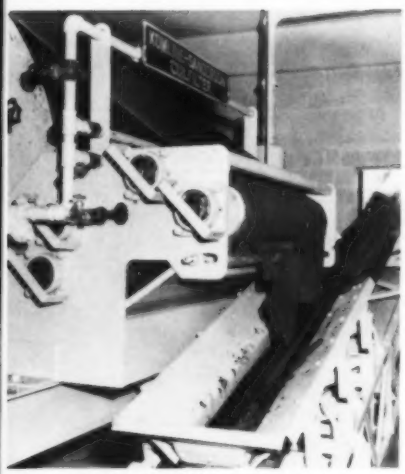
FRESH SLUDGE DEWATERING

Fresh Sludge Dewatering has gained acceptance at a constantly accelerating rate. Komline-Sanderson engineers have shown from experience and from plant operating data that fresh sludge can be dewatered at a higher rate than digested sludge, and with lower chemical requirements.

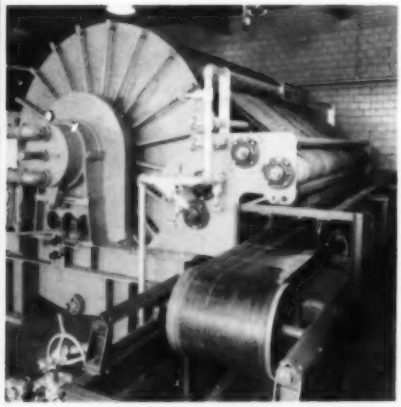
Successful filtration of fresh sludge is dependent upon the maintenance of an open non-clogging, non-blinding filter medium, such as is available only with the Coilfilter.

Dewatering of fresh sludge is accomplished on the Coilfilter without odor or other nuisance. The

At top of page: Two 300 Sq. Ft. Coilfilters at Woodbridge, N. J.
Engineer: Louis P. Booz



100 Sq. Ft. Coilfilter package unit at Elizabethton, Tenn.
Engineers: Allen & Hoshall



250 Sq. Ft. Coilfilter at Middletown, Ohio
Engineers: Floyd G. Browne & Associates

filter cake is stable and is readily disposable. Bacteriologically, dewatered fresh sludge contains low, if any coliform density.

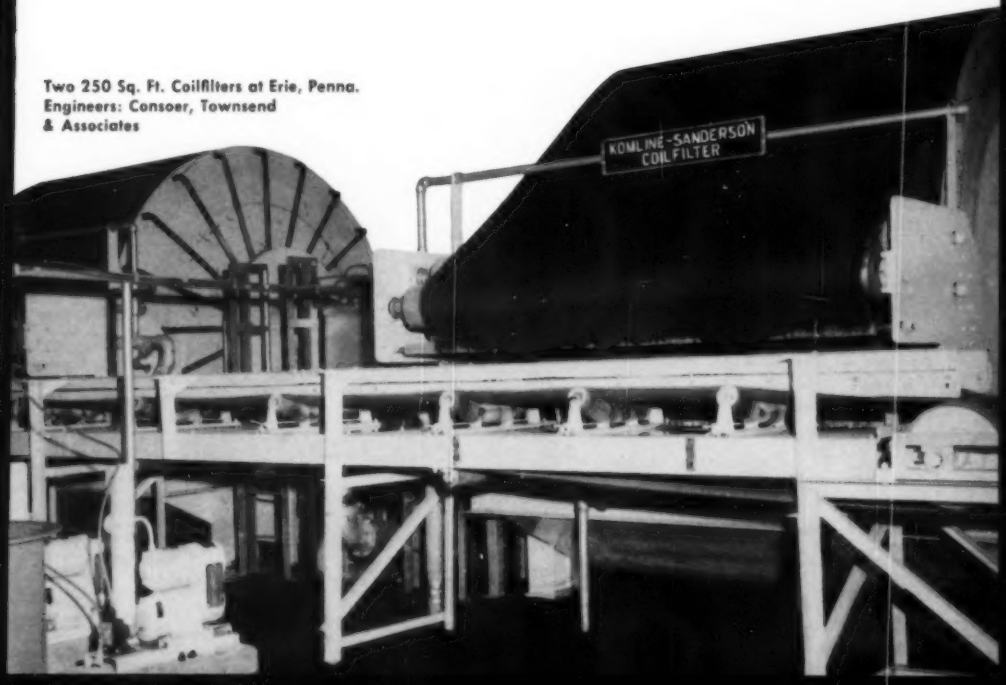
COILFILTER DEWATERING OF FRESH SLUDGE OFFERS THESE ADVANTAGES:

1. Lower capital investment.
2. Lower plant area requirements.
3. Simplified sludge disposal.
4. Improved plant operation through greater flexibility.

PERFORMANCE

Coilfilter cake production is greater than from any other type of sludge dewatering equipment. Output is uniform because the filter will not clog or blind. Down time is unnecessary because the media does not require hand cleaning. Chemical conditioning is far less critical than with other types of vacuum filters. Standby filters are not needed.

Two 250 Sq. Ft. Coilfilters at Erie, Penna.
Engineers: Consoer, Townsend & Associates



Some recent COILFILTER installations in operation or under construction.

Sewickley, Penna.
Dubuque, Iowa
Easton, Penna.
Spring Valley, N. Y.
Ashland, Ohio
Willimantic, Conn.
Elizabeth, Penna.
Penn Township, Pa.
Nassau County, N. Y.
Zanesville, Ohio
Bedford Heights, Ohio
Suffern, N. Y.
Beatrice, Neb.
Mansfield, Ohio
Traverse City, Mich.
Sandusky, Ohio
Orange City, Iowa
West Lafayette, Ind.
Norfolk, Neb.
Whitemarsh, Penna.
Baden, Penna.
Marceline, Mo.
Omaha, Neb.
Manitowoc, Wis.
Superior, Neb.
Ogallala, Neb.
Regina, Canada
Kiamesha Lake, N. Y.
Jonesboro, Ark.
Boone, Iowa
Holdrege, Neb.
Somerset-Raritan Valley, N. J.
Muskegon, Mich.
Toronto, Canada
Fairbury, Neb.
Spring Valley, Ill.
Rochester, N. Y.

LABORATORY SERVICES

Komline-Sanderson maintains completely equipped and staffed laboratory facilities at the plant in Peapack, New Jersey.

In addition to carrying on basic investigations, constantly conducted to improve the technology of sludge dewatering, our laboratory offers an important part of our direct service to our clients.

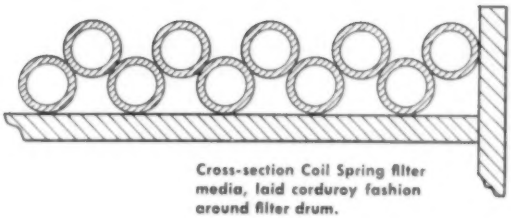
INSTALLATION

Every Coilfilter installation receives the same careful attention from our engineering staff. In order to assume responsibility for the proper performance of the complete sludge dewatering installation, we prefer to handle all necessary equipment.

1. Coilfilter
2. Vacuum and Filtrate Equipment
3. Conditioning tanks
4. Wet sludge handling equipment
5. Chemical feeders, pumps and tanks
6. Cake handling equipment

WARRANTY

The Coilfilter is unconditionally guaranteed to work satisfactorily and filter continuously, without clogging or blinding, provided that the sludge is conditioned to the following laboratory requirements: Utilizing a No. 2A Buechner funnel and working with a 100 cc sample, the sludge is to dewater to a cake of one-quarter inch thickness in 100 seconds.

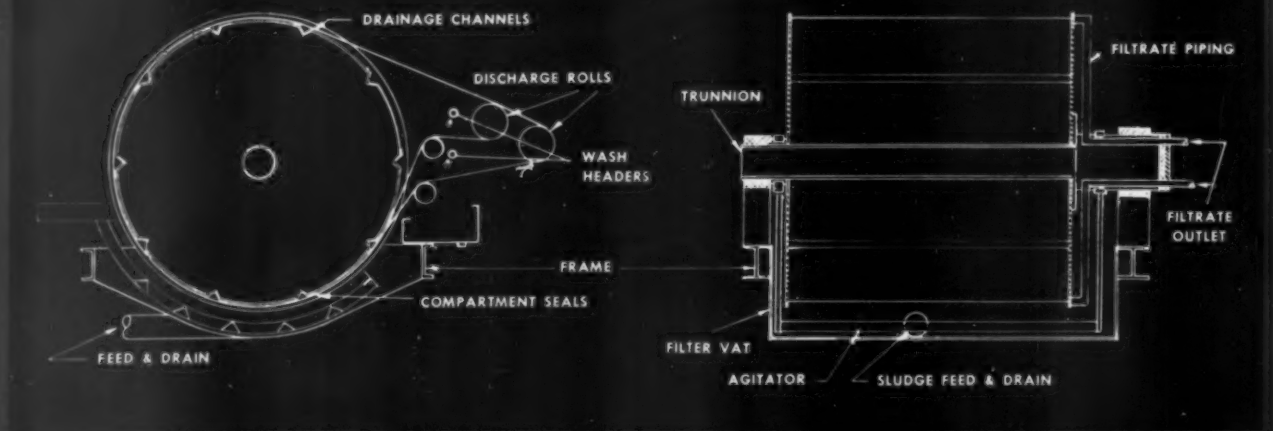


Cross-section Coil Spring filter media, laid corduroy fashion around filter drum.

Manufacturer warrants all equipment and parts for one year and shall maintain the filter media without charge for a period of 10 years after shipment if the filter unit is operated 40 hours per week, or its adjusted equivalent.

COILFILTER STANDARD SIZES	
SIZE	AREA SQ. FT.
*7' x 4'	85
*7' x 5'	100
*8' x 4'	100
8' x 5'	125
8' x 6'	150
8' x 8'	200
10' x 6'4"	200
10' x 8'	250
10' x 10'	300
10' x 12'	350
11'6" x 10'	350
11'6" x 12'	430
11'6" x 13'	470
11'6" x 14'	500
11'6" x 15'	540
11'6" x 16'	575

*Package Unit



Methods of Handling Dried or Incinerated Sewage Solids

by ROBERT K. HAMPTON, P. E.
Manager New York Office, Beaumont Birch Co.

THE DISPOSAL of solids removed from sewage presents an increasingly difficult problem to cities of all sizes due to high land values and increasing labor costs. Drying of sewage sludge of beds requires area, not only for the beds but also for ultimate disposal of the dried sludge. Drying of sludge in furnaces for use as a fertilizer or soil conditioner offers another method of disposal. Incinerating the sludge to a sterile ash offers still another method of disposal which requires less area for ultimate disposal.

Drying of filtered sludge solids for soil conditioner or fertilizer presupposes that there is a market which can be developed economically. Incinerating the sludge results in less solid matter to handle. In either of these cases, handling or conveying of the burned sludge ash or dried sludge is an item too often given scant attention in overall plant design. Proper study of the conveying problem in the initial stages of plant design can result in sizeable economies both in capital investment and operating costs.

Methods of Handling Solids

If solids are dried or incinerated, they are first dewatered, then handled in drying or incinerating furnaces. In either case the solids may be handled in several ways. Figure 1 shows a flow diagram of the various methods of handling and disposing of sewage solids, either fresh or digested.

Incineration or Drying

When solids are incinerated and a lagoon or fill area is available, hydraulic pumping of the ash is simple, adaptable and trouble-free. Hydraulic systems can handle most types of ash regardless of temperature; small clinkers or stones; it can convey the ash to a final disposal point without intermediate handling.

When land conditions prevent the use of lagoons, storage bins are used to store the ash dry. The stored ash in the bin may be hauled away periodically, usually by truck, to a convenient fill area. Mechanical conveyors, such as screw conveyors for horizontal conveying and bucket elevators for vertical lifting, are commonly used to convey dry ashes from underneath the furnace to the storage bin. Pneumatic conveyors have also been used in certain instances to convey ashes from under the furnace to the bin.

When drying is utilized either by itself or in conjunction with burning, the type of conveying equipment is dictated mainly by the type of furnace selected. For the flash drying type of furnace, pneumatic conveying is used not only to convey, but as an integral part of the process. For multiple hearth furnaces the dried sludge is usually conveyed mechanically by means of screw conveyors and bucket elevators.

Hydraulic Ash Handling

The component parts of a hydraulic ash handling system, as shown in Fig. 2, are a steel ash hopper or concrete sump for receiving the ash discharged from the furnace and for storing it for a short time, a centrifugal pump with electric motor, discharge pipeline to lagoon, electric controls either manual or automatic and water supply for agitation and make-up.

The ash hopper is usually made of steel plate preferably conical in shape and equipped with sizing grid, access doors, agitator nozzles, float controlled make-up valves, drain, overflow and pump suction pipes. A steel hopper is shown in Fig. 3. Concrete sumps have the same appurtenances as steel hoppers but are arranged to suit sump design. The size of hopper is determined by the amount of ash storage desired (usually a minimum of one hour) and the minimum water level required for proper pump suction. Too often hopper design has been dictated by furnace heights, set before considering the ash handling system requirements.

Ash Pumping

The ash pump is usually a centrifugal type with a fully shrouded impeller with the passages opened to handle solids, etc. The impeller is

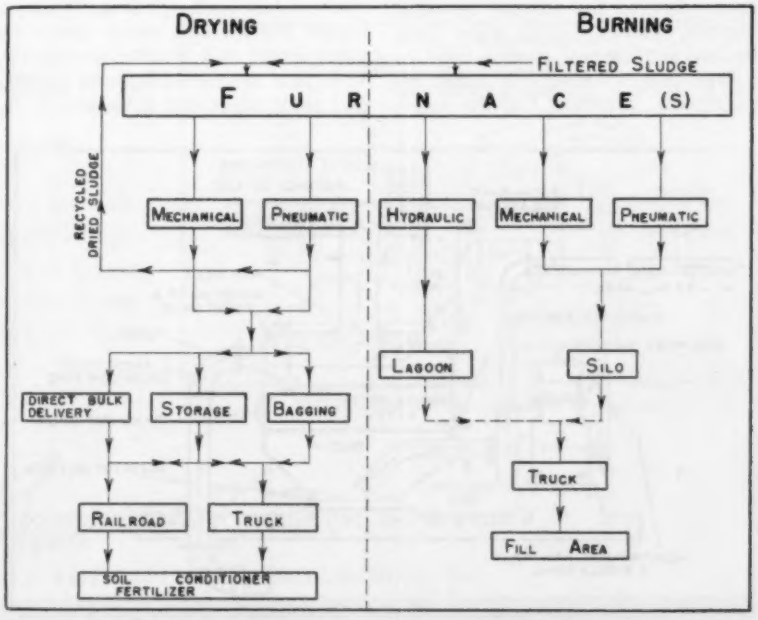


Fig. 1—FLOW DIAGRAM for handling dried or burned sewage sludge solids.

normally made of abrasion resisting metal, such as "Ni-Hard." High pressure water is used to keep grit out of the stuffing box and to reduce wear at the suction seal. The pump size depends mainly on pipe size. The pump motor horsepower generally varies from 15 hp using a 3-inch pipe line up to 500 feet long to 50 hp or more using a 6-inch pipe line 2000 feet long. The actual pipe line contour together with the number of elbows and segregating valves and difference in elevation between the discharge end of the pipe line and free water level in the ash sump will, of course, determine the actual horsepower.

Pipe size varies both with pipe line length and capacity desired. For small plants with one or two furnaces 3 inch diameter up to 500 feet and 4 inch diameter up to 2000 feet in length are normally used. With large furnaces or three or more medium size furnaces, 4-inch pipe for the short lines and 5-inch or 6-inch pipe depending on capacity required are used on long pipe lines. Eight inch lines are infrequently used and only when very high capacities are required or pipe lines losses due to many bends indicate more economical horsepower requirements.

Water requirements vary with pipe size, capacity requirements and pipe line configuration. The amount varies from 150 gpm in short 3-inch lines to 900 gpm in long high capacity 6-inch lines. High pressure agitator and pump seal water depends on the size of the hopper usually about 120 gpm at 50 to 60 psi for each hopper and pump. Due to the amount of water required, filtered effluent water from the final settling tank is often used for a large proportion of the water requirements. Strainers and the consequent manual cleaning of the strainers is the only added operational problem. City water is still desirable for pump seals and agitator nozzles.

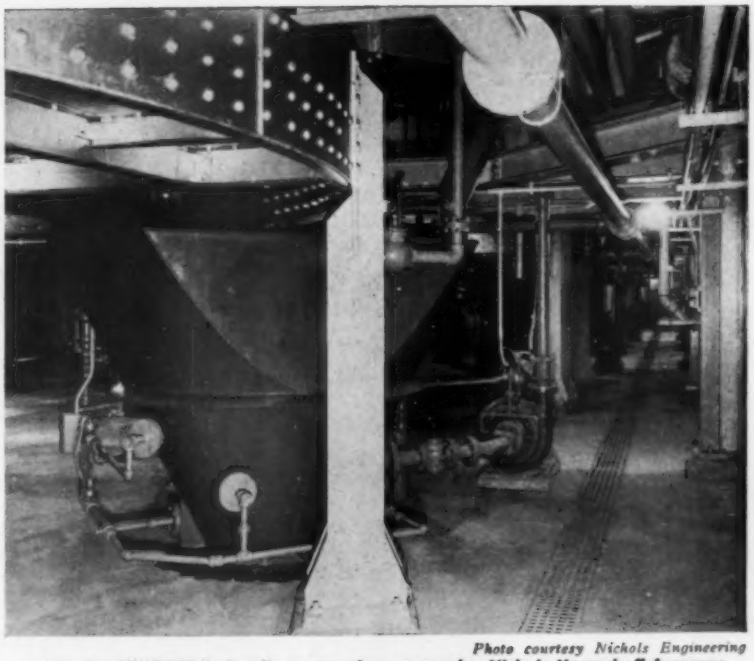


Photo courtesy Nichols Engineering

Fig. 3—MULTIPLE hydraulic storage hoppers under Nichols Herreshoff furnaces.

Hydraulic System Operation

Operation of hydraulic systems may be manual or automatic. On manual operation the operator starts the ash pump motor and then opens vertical ash pit doors on some types of furnaces. On other types of furnaces where ashes discharge directly into a hopper the operator merely starts the pump motor on a predetermined cycle. It is best to control agitator nozzles and pump seal water automatically by means of solenoid valves rather than depend on the operator to open manual water valves.

On automatic systems the pump motors, agitator nozzles and pump seal water are automatically turned on by a time clock or float control system and stopped after a predetermined time. The normal water level is maintained by independent float controlled valves. If effluent water is used it is better to use pilot operated valves on the make-up lines. When several furnace hoppers empty into a common discharge line special segregating valves are required. A common collecting hopper may be used to eliminate the maintenance and operating problems encountered with material occasionally clogging segregating valves. The common hopper also allows two or more hoppers to discharge simultaneonsly through a common pipe line.

Mechanical Solids Handling

Mechanical handling of burned sludge ash has usually been done by discharging the ash continuously into a centrifugal-spaced bucket elevator, and continuously discharging the ash from the elevator into a storage bin. When furnace height is limited, a screw feeder, as shown in Fig. 4, may be used to feed the elevator boot. To keep elevator height to a minimum (and when bins are some distance from the elevator) horizontal screw conveyors may be used to convey ash to or from the elevator.

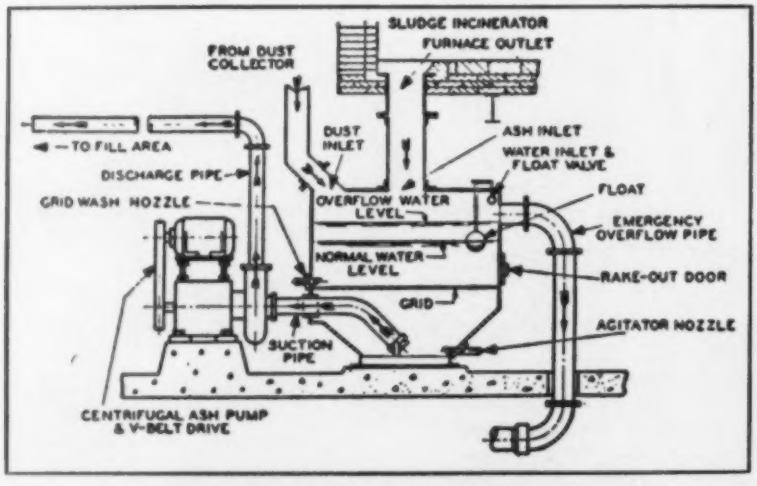


Fig. 2—CROSS SECTION of hydraulic ash hopper.

Beaumont HYDRAULIC ASH HANDLING

For Conveying Incinerated Sewage Sludge Ash

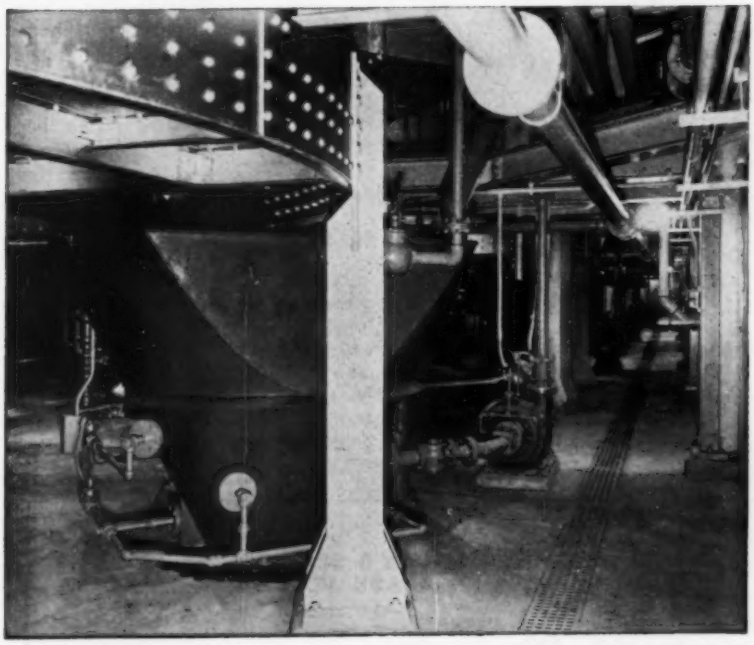


FIG. 1—Multiple Hydraulic Storage Hoppers at Indianapolis, Ind. Sewage Treatment Plant. Similar systems now being installed at: Nashville, Tenn., Grand Rapids, Mich. and Rochester, N. Y. Sewage Treatment Plants.

Outstanding Features

Controls automatically adjust to furnace burning rates, thereby saving power costs and water usage.

Use of treated effluent water eliminates water supply problem.

Direct conveying to nearby final disposal site without additional labor or trucking costs.

Can readily handle hot and partly burned ash

Completely enclosed system provides dustless operation.

Other Beaumont Birch Equipment

Mechanical & Pneumatic Conveyors for handling Dried or Incinerated Sewage Sludge; Charging Gates, Charging Skips, Ash Gates and Residue Conveyors for Incinerators. Coal and Ash Handling Epuipment for Power Plants & Boiler Houses. Rotary Feeders—all types.

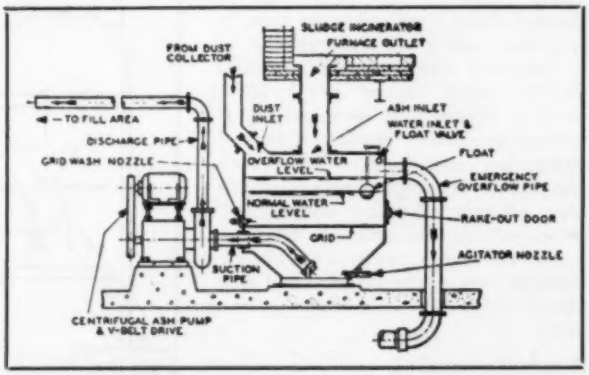


FIG. 2—Cross Section of Hydraulic Ash Hopper.

Beaumont BIRCH COMPANY

1512 RACE STREET, PHILADELPHIA 2, PA.

DESIGNERS—MANUFACTURERS—ERECTORS BULK MATERIAL HANDLING SYSTEMS

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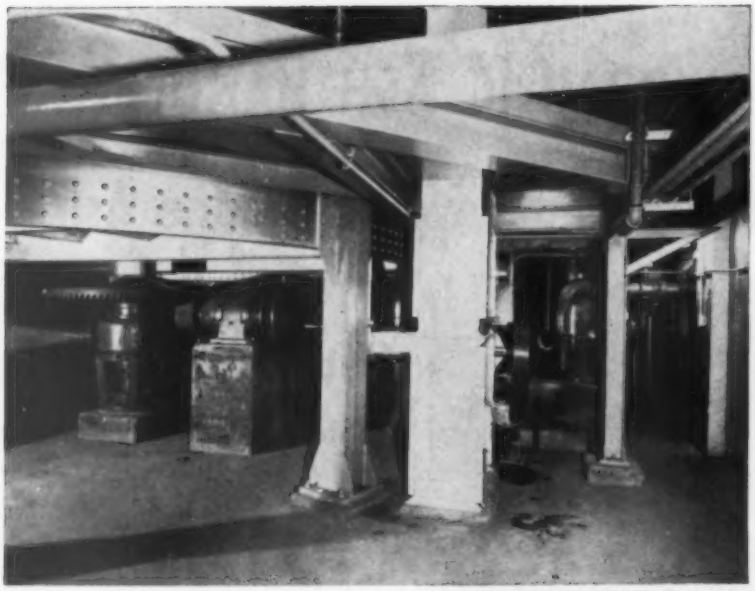


Photo courtesy Nichols Engineering

Fig. 4—BODY of bucket elevator being fed by screw feeder.

Horsepower requirements vary from 2 hp for an 8 x 5-inch elevator 60 ft. high handling 3 tons per hour to 5 hp for a 20 x 8-inch elevator handling 15 tons per hour.

Careful attention must be given the manner of furnace discharge as this usually determines elevator capacity required. Since the ash is dusty, it is desirable to keep elevator speeds to the minimum compatible with proper discharge. Perfect discharge type elevators which can operate at much lower speeds have been used in a few cases. However, their higher cost has limited their application in spite of less dust and lower maintenance.

Standard screw conveyors wear rapidly under burned ash handling service. Heavy duty sectional flights, sometimes further reinforced by stelliting, last much longer. To increase the life of bearings conservative design of capacity using not over ⅓ cross section area and also feed sections will help greatly. Conveyor troughs can easily be renewed and, therefore, in most cases liners are not used.

Pneumatic Handling

Pneumatic handling of burned sludge may be used. The normal advantages of pneumatic conveying are not realized unless continuous conveying of a uniform product can be achieved. In the flash drying type furnace the conveying system is of this type. On multiple hearth furnaces, however, where discharge is intermittent and the conveying system is not an integral part of the process, the cost of a continuous type pneumatic system and its high power requirements usually outweight any advantages over a mechanical handling system.

Intermittent type pneumatic conveying systems as shown in Fig. 5 have been used. In order to make them economically feasible both from a capital investment and power operating cost standpoint, the ash is usually stored for a period of an hour or two and then is conveyed in a system sized to handle the material in a few minutes. The nature of sewage ash is such that once it is stored it is hard to get moving freely from a hopper and this requires some manual attention to assure cleaning of hoppers. The power requirements vary from 15 hp for a small 4-in. system handling 2 to 5 tons per hour up to 60 hp for a 6-in system handling 12 tons per hour.

Storage

Storage bins are usually one of two types, circular steel with conical bottoms or glazed tile. If the temperature of the ash is expected to go over 600 or 700 degrees a steel bin will withstand the heat better. However, condensation may be a problem in cold climates in steel bins.

When discharging from bins into

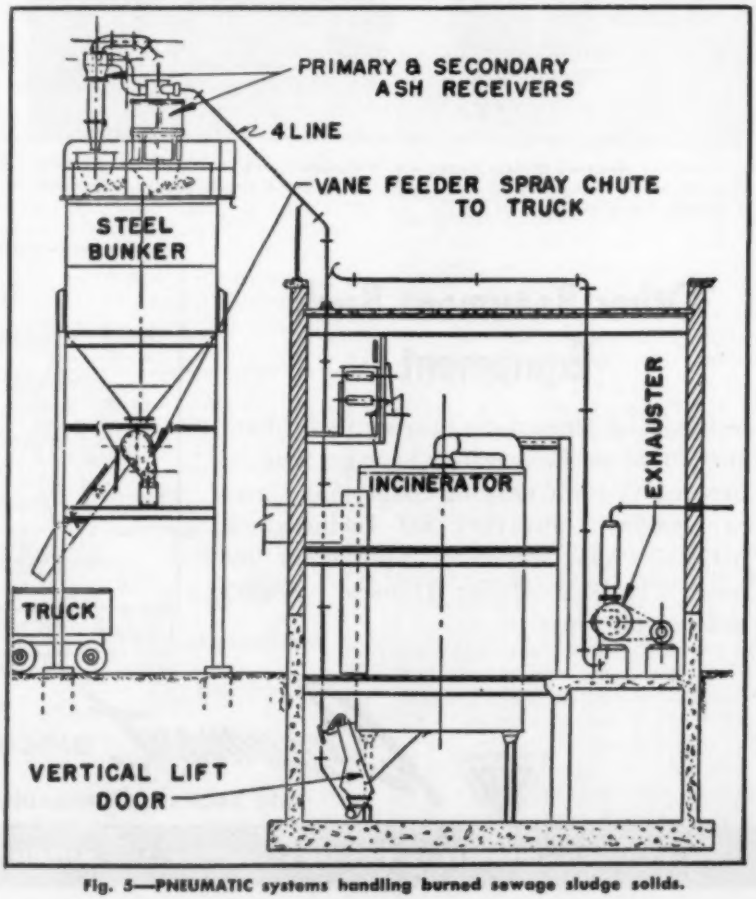


Fig. 5—PNEUMATIC systems handling burned sewage sludge solids.

trucks or railroad cars some provision must be made to hold down dust. Most plants use a rotary drum type mixer with internal water sprays. Once the operator regulates the water to suit the ash this is a very effective unit. To cut down cost some plants discharge dry into trucks using a gate or preferably a feeder to control the flow. A cloth or tarpaulin is usually spread over the truck body and this keeps dust to a minimum; these is still a dust problem when the truck is dumped at the fill area.

Costs and Power Requirements

The total cost for conveying equipment would vary with each installation due to capacity, hours of operation and availability of storage space. This is especially true when sludge is dried. Therefore, general costs for this type operation are not included. However, with respect to handling the ashes from burning the capital costs can be approximated and Table 1 gives an indication of what these costs would be for the various types of systems. The costs for the hydraulic system are complete, that is to the point of final disposal which would be a fill area on the plant site. However, with respect to the pneumatic or mechanical conveying systems the cost of trucking to a final disposal area has not been included and vary considerably for each location.

The power requirements are also given only for handling burned sludge solids. Here again the power requirements for hydraulic systems are for complete handling to the point of final disposal. For mechanical and pneumatic systems the operating power requirements derived from cost of trucking or other means of transportation to point of final disposal must be added.

TABLE 1

Capital Costs and Power Requirements

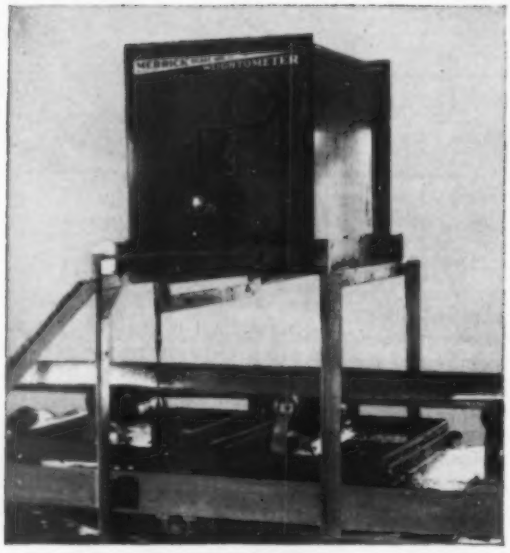
Type System	Capital Cost per Ton of Dry Solids Burned/Day		Power Requirements KWH/Ton Burned	Remarks
Size Installation	Large	Small	All	All
Hydraulic	350	600	2.0	Conveys direct to final disposal area
Mechanical	500	1100	1.0	Add to these figures the cost of trucking to final disposal area
Pneumatic	600	1200	3.0	Add to these figures the cost of trucking to final disposal area

Summary

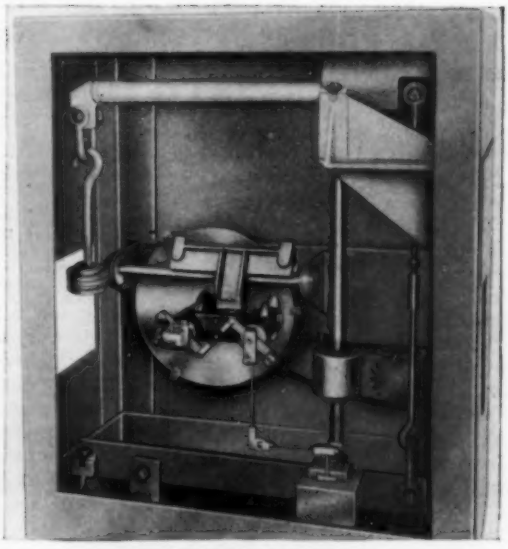
For handling burned ash from sewage sludge incineration, the hydraulic type of system is preferable when adjacent land is available. If storage in a bin adjacent to the plant is desired, mechanical handling appears to be most foolproof at the present time. When handling dried sludge for use as fertilizer, the pneumatic system for the flash drying system and mechanical handling for multiple hearth furnace appears to be best.

Make a continuous, accurate record of filter cake weight with a...

MERRICK WEIGHTOMETER®



Type E Weightometer.



Type SV Weightometer.

Accurate totals of the solids are easy when a sewage treatment plant has a Merrick Weightometer. The Weightometer continuously records the total weight of filter cake or sludge carried on a moving conveyor by measuring and integrating the varying load on the conveyor with the fluctuating speed of the belt. Proved by fifty years' use in every type of bulk materials handling found in industry, the basic principle of the Weightometer has been refined until accuracies of better than 0.5% can be guaranteed.

Any weight, any material, any capacity... There are no limits to the Weightometer's applicability. Any material, wet or dry, that can be carried on a conveyor can be weighed, accurately and continuously, with the total weight registered. There is no interference with the operation of the conveyor or the flow of material.

Compact, easy to install, operates by itself... The Weightometer can be readily installed on your existing conveyor without altering the conveyor's structure (see cut). It needs no extra floorspace. And since its operation is entirely automatic, no attendant is needed.

Negligible maintenance... All essential parts of the Weightometer are enclosed, effectively protecting them from dust and dirt and also preventing tampering by unauthorized personnel.

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Sewage Solids Incineration Costs

by KERWIN L. MICK and SCOTT E. LINSLEY

Chief Engineer and Assistant Engineer, Minneapolis-St. Paul Sanitary District

A COMPREHENSIVE examination of sewage solids incineration costs can serve several useful purposes, as follows:

1. It can aid in determining whether or not incineration is the proper method of final solids disposal for a particular sewage treatment objective.

2. It can determine which of the incineration systems available is the most economical to operate.

3. With similar systems, it can provide a basis of comparison for properly operating the system and set guides and limits to maintenance, attendance, and other service factors in order to obtain maximum capacity and efficiency.

In order to properly evaluate each of these purposes, however, an understanding of the problems involved and their various facets must be obtained. It must be recognized first of all that the incineration operation cannot be considered completely independent of the other sewage treatment processes, as to do so would result in failure to obtain a proper balance between investment cost and operating cost and, thus, an improper total vestance[1].

That the foregoing statement is true will be immediately apparent if we consider that the nature of the material to be burned is drastically affected by the manner in which the solids in the sewage are handled. Sewage solids as removed normally include screenings, grit, scum, and sludge. Each of these items contains varying amounts of water, volatile or combustible matter, and ash.

Further, the fuel value on the basis of Btu's per pound of dry solids varies. This variation is particularly apparent when raw sludge is compared with digested sludge.

Also, simple mathematics shows that a minimum of water is desirable if combustion is to be self-sustaining (without the use of expensive fuels). A little investigation will demonstrate that in order to obtain a reasonably economic incineration heat balance, additional dewatering of the sludge is essential beyond simple concentration. This is commonly accomplished by vacuum filtration.

Thus, until newer, more economical methods are proven, the vacuum filtration process must be considered as an integral part of the incineration operation. For the purpose of adequate cost control, detailed information must be available on each department[2].

A system is involved; therefore, a system study is in order. No part of the system can be omitted from consideration or the whole will not be properly evaluated.

Further, when comparing capital costs, the prevailing wage rates in a given area are of importance as well as the time of construction. Because the value of the dollar has varied widely in recent years, it is important that original capital investments be re-evaluated in terms of present-day replacement costs. For purposes of this discussion, the *Engineering News-Record* Construction Cost Index is used as a basis for comparison.

The sewage and industrial wastes field suffers from a lack of uniformity in accounting and reporting procedure[3]. This is due in part to process differences, trade secrets, patents, and magnitude of the art. The principal reason for public utility reporting divergence probably is due to the area of responsibility and the political organizational limits involved. Thus, those factors for which an organization is not responsible will not ordinarily be reported by the individual in charge.

It is suggested that regardless of the organizational responsibilities involved, a uniform system of accounting for sanitary districts and sewage plants be adopted showing full and complete costs on a comparable process basis. Thus, the principal Roman numeraled operating and capital cost divisions listed hereinafter should be expanded to provide for other major items such as interceptors, pumping, aeration, biological filtration, digestion, and lagoon or drying bed operation, including hauling.

To rationalize performance and cost data acquired from various sources, Table 1 has been prepared showing a comparison of sewage treatment plant costs and accomplishments for four different cities. The bulk of this information has been compiled or computed from the annual reports of the organizations cited in the references or from other sources shown. This table provides a common ground for comparing data, or points out the lack thereof as the case may be.

The sewage treatment plants of Buffalo, N. Y.; Cleveland, Ohio; Detroit, Mich.; and Minneapolis-Saint Paul, Minn., were selected for comparison because they all operate incinerators, publish extensive annual data, and are of similar magnitude. The degree of treatment and the nature of some of the processes vary between the different plants; but there are some comparable processes, and these are the ones discussed in the following.

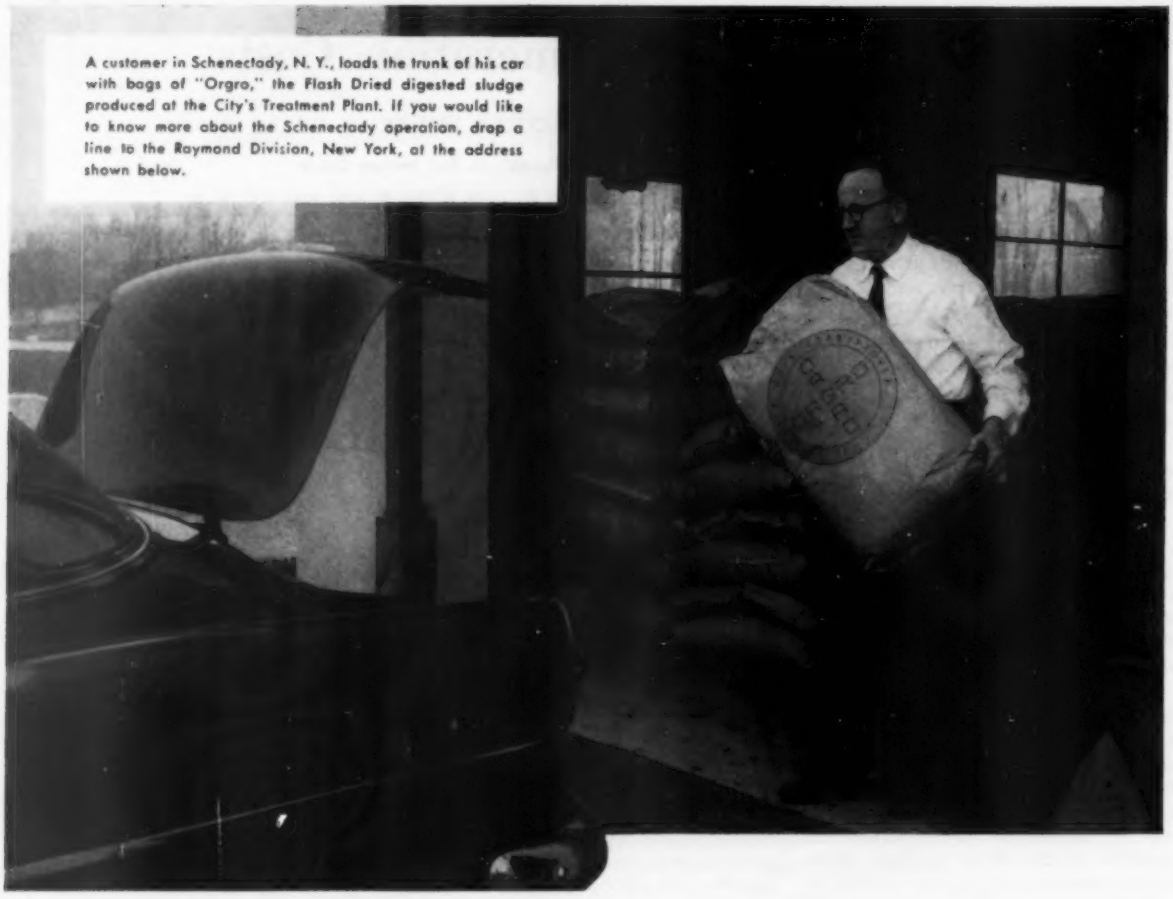
Operating Costs

To ensure as far as possible that similar items are compared and that a proper reporting basis has been achieved, a brief discussion of the cost figures in Table 1 follows:

The total operating expense, Item 11, is not comparable for the cities cited. This is true because of differences in size of the cities and a number of other factors, such as hydraulic characteristics, type of treatment, etc. Sewage flow in the Minneapolis-Saint Paul area is approximately 98 percent by gravity; thus, the pumping costs are negligible at this plant. Cleveland's sewer system is also largely gravity flow, although some 20 mgd (about 11 percent) are pumped and these costs are largely charged to the Easterly plant. Conversely, all of Detroit's and Buffalo's sewage is pumped.

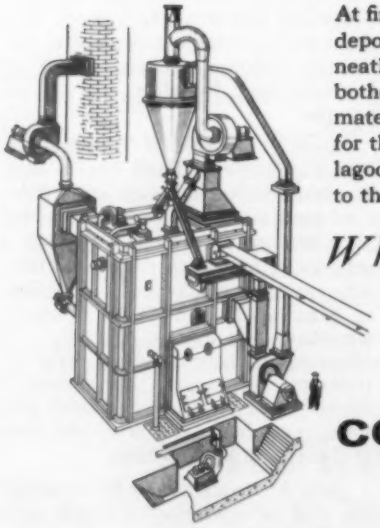
Further, chlorine is not used at Minneapolis-Saint Paul, but is used in considerable quantities at Buffalo, Cleveland, and Detroit. Costs reported for Cleveland and Detroit include a substantial figure for depreciation, whereas none is allocated for Buffalo or Minneapolis-Saint Paul. Buffalo, Cleveland Westerly, Detroit, and Minneapolis-Saint Paul are primary treatment plants only, but Cleveland Easterly and Cleveland Southerly perform secondary treatment and thus are most costly to operate.

Item 30, another basis for reporting the cost of operation, is more comparable and uniform because it includes the operating costs for all



A customer in Schenectady, N. Y., loads the trunk of his car with bags of "Orgro," the Flash Dried digested sludge produced at the City's Treatment Plant. If you would like to know more about the Schenectady operation, drop a line to the Raymond Division, New York, at the address shown below.

Can you think of a better way to dispose of sewage sludge?



At first glance, the trunk of a car may seem to be a peculiar place to deposit sewage sludge. But when the sludge is dry, sterile and neatly packaged, it can be a marketable commodity rather than a bothersome waste. When uncontaminated with noxious industrial materials, it is an excellent soil conditioner. Its sale produces revenue for the treatment plant, eliminates the nuisances of drying beds, lagoons and ash disposal and, at the same time, renders a service to the people of the community.

What's the best method of drying sludge?

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ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

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Table 1—Comparison of Sewage Treatment Plant Costs and Accomplishments

Item No.	Item	Computation Reference	Unit	Buffalo [4] Fiscal Year 1955-1956	Cleveland [5] Calendar Year 1955*	Detroit [6] Fiscal Year 1955-1956	Mpls.-St. Paul [7] Calendar Year 1955
	General load data:						
1.	Connected Population	———		576,000	1,229,029†	2,600,000	958,000
2.	Population equivalent	———		786,000	1,658,228†	2,620,000	1,510,000
3.	Area served	———	Sq Mi	42	109	331	229
4.	Sewer system length	———	Miles	775	Not avail.	2,770	2,038
5.	Plant effluent flow	———	Avg. Cfs	222	53 W 158 E 92 S	735	210
6.	Flow in river at outfall	———	Avg. Cfs	200,000	Lake Erie plus 295	177,000 [8 9]	7,410
7.	Rainfall (total for year)	———	In.	44.0	39.6	33.3	21.1
8.	Effluent 5-day BOD avg.	———	Ppm	84.0	137 W 13.2 E 70 S‡	82.6	155
9.	Plant construction cost	———	$	5,209,826.35	16,852,378.21	10,726,551.35	3,932,762.49
10.	Date of completion of original plant constr.	———	Yr.	1939	1932-1936 W 1938 E, S	1940	1938
11.	Total operating expense	———	$	779,726.43	2,119,737.17	2,623,706.62	829,326.83
12.	Sewage treated:	———	Mg	52,172	71,647	173,714	48,272
13.	Avg. sewage strength (sus. solids)	———	Ppm	146	256 W 196 E 224 S	225	284
14.	Removal of sus. solids by plant	———	%	34.2	29.4 W 93.0 E 25.9 S‖	48.1	70.7
15.	Removal of 5-day BOD	———	%	23.6	25.1 W 90.2 E 50.9 S‖	30.6	35.4
16.	Avg. sewage strength in 5-day BOD	———	Ppm	110	183 W 135 E 143 S	119.1	240
	Removal of dry solids:						
17.	Screenings and trash	———	Tons	651	37¶	Incl. in scum and sludge	138
18.	Grit	———	Tons	1,354	7,086☆	12,123	10,012
19.	Scum	———	Tons	Incl. with sludge	Incl. with sludge	1,189	1,057
20.	Sludge	———	Tons	7,508	39,188	79,950	44,126
21.	Total	———	Tons	9,513	46,311	93,262	55,333
	Removal of volatile matter:						
22.	Screenings and trash	———	Tons	Not avail.	Not avail.	Incl. in scum and sludge	122
23.	Grit	———	Tons	551	2,679	3,633	1,041
24.	Scum	———	Tons	Incl. with sludge	Incl. with sludge	1,070	1,034
25.	Sludge	———	Tons	5,040	29,120	48,897	31,991
26.	Total	———	Tons	5,591	31,799	53,600	34,188
27.	Removal of 5-day BOD:	———	Tons	5,660	28,056	26,332	17,120
	Sludge conditioning chemicals, % of dry weight of sludge solids:						
28.	Ferric chloride (or equiv.)	———	%	4.41	3.04 W 3.8 S	1.07	0.47
29.	Calcium oxide (lime)	———	%	17.22	13.1 W 12.1 S	10.53	2.42
30.	Cost of operation●:	———	$	487,959.41	1,561,566.34	1,133,394.74	829,326.83
31.	Cost per mg treated★	30/12	$	9.35	21.80	6.53	17.18
32.	Cost per ton dry solids removed★	30/21	$	51.29	33.72	12.15	14.99
33.	Cost per ton volatile matter removed★	30/26	$	87.28	49.11	21.14	24.26
34.	Cost per ton BOD removed★	30/27	$	86.21	55.66	43.04	48.44

* Three plants: W = Westerly, E = Easterly, S = Southerly.

† For calendar year 1956.

‡ Weighted average effluent BOD, including supernatant liquor from digestion tanks discharged to outfall sewer.

‖ Neglecting the supernatant liquor discharged to the outfall sewer, the suspended solids removal increases to 72.5% and the BOD to 67.9%. This plant processes all of the Easterly plant's sludge in addition to that removed locally.

¶ Screening dry solids = 7.5 lb per cu ft (estimated), balance in sludge.

☆ Grit: Dry solids = 85 lbs per cu ft (estimated).

● Chlorination, depreciation, and pumping costs excluded.

★ Items 31 through 34 are partial unit costs, but are truly comparable. See text for discussion of cost comparability. Actual over-all costs are seldom comparable between different plants. Detroit Annual Report, for example, present over-all costs as follows:

Total cost of sewage disposal operation and maintenance, 1955-6.....$2,623,706.62 (Item 11).

Cost per million gallons =.....$ 15.10 instead of $6.53 (Item 31).

Cost per ton solids disposed of by incineration (dry basis) (including chemicals) (Item 11, Table 1 ÷ Item 32, Table 2) =.....$ 31.13 instead of $12.15 (Item 32).

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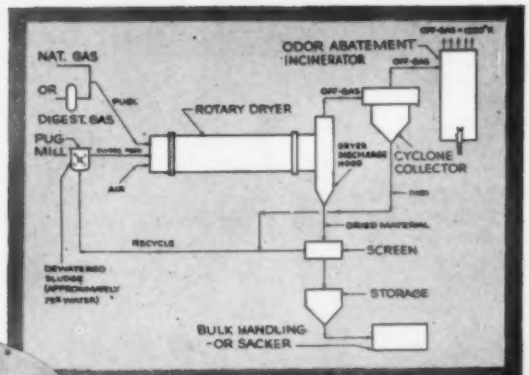
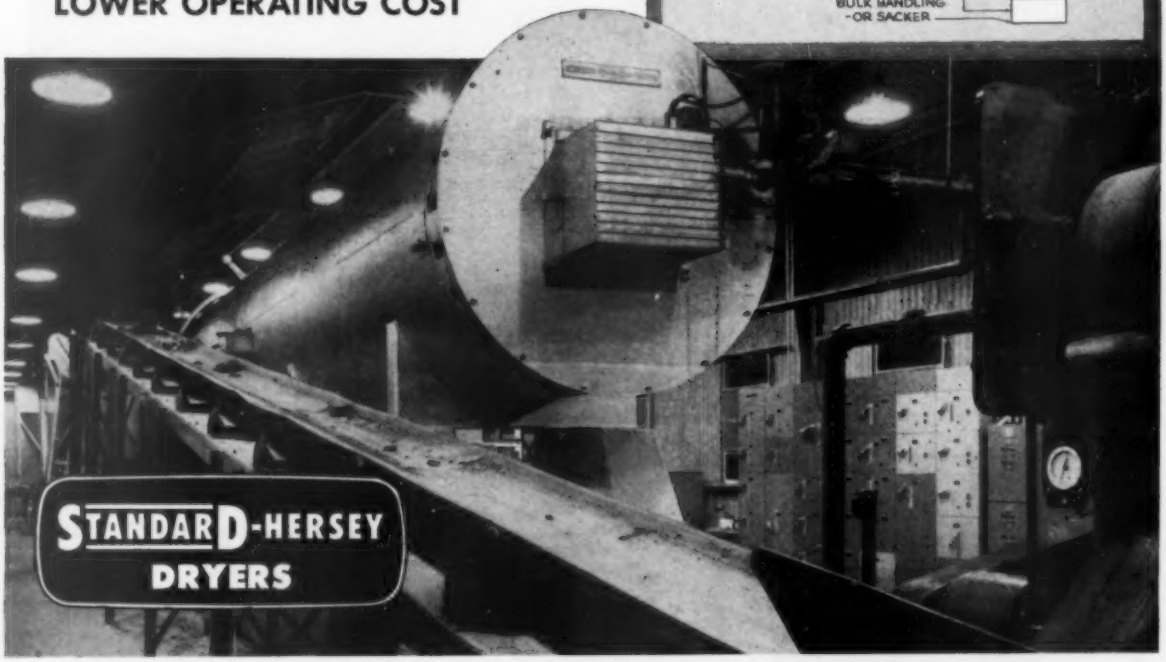
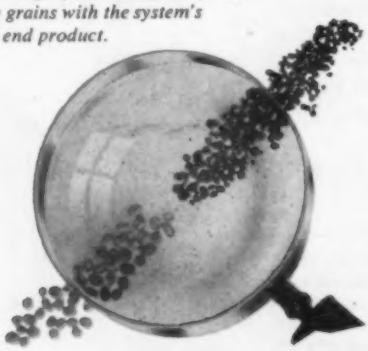




Actual photograph showing comparison of barley grains with the system's granular end product.



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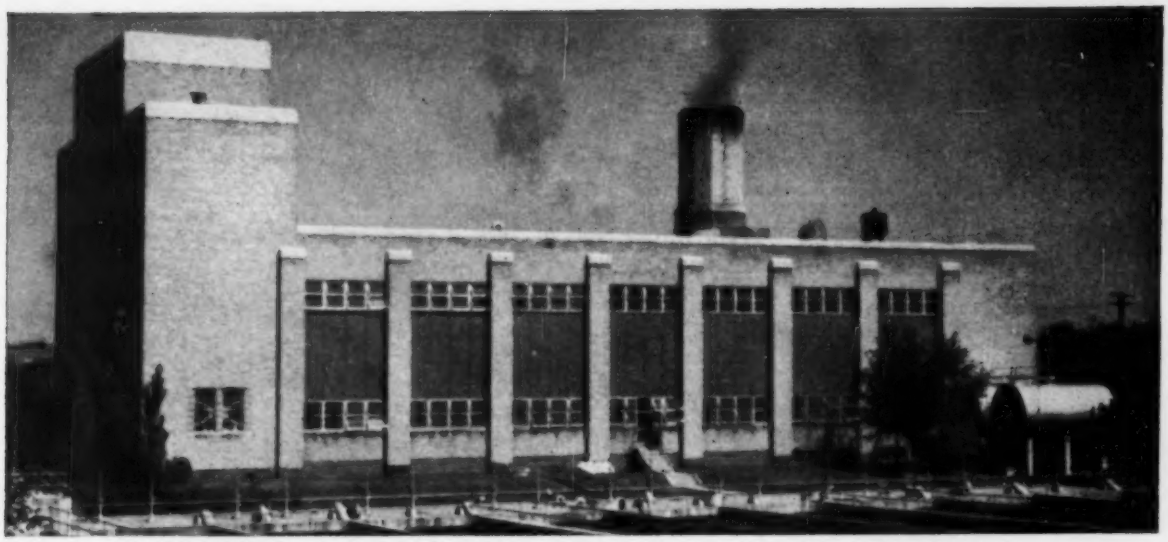


SLUDGE filtration and incineration building concentrates all processes of dewatering in one unit.

plants, less chlorination, depreciation, and pumping costs allocated, plus the proportionate share of administrative costs including billing and collection. The unit costs in Items 31 through 34 inclusive, are based on Item 30 divided by the appropriate quantities shown.

Table 2 has been prepared with the objective of segregating the different processes pertaining to the various materials removed from the sewage, with particular emphasis on those directly related to incineration. The total process cost, Items 55 through 58 in Table 2, is extracted from Item 30 in Table 1 and includes all the properly chargeable overhead, but excludes depreciation.

The direct process costs in Items 43 through 46 are all the process costs, including maintenance, but less administrative overhead charges.

The unit costs shown in Table 2 are largely self-explanatory, but a few comments are in order. The unit costs shown in Items 49, 51, 61, and 62 are proportionally lower for Detroit when compared to the other plants, due to grit incineration at Detroit.

Certain technical data have been included in Table 2 as they have a bearing on cost. For example, to properly analyze heat balance factors the ultimate analysis of the sludge must be known. Further, if this analysis is performed on the sludge cake, proper consideration of the quantity and kind of chemicals added will have to be made in order to accurately calculate the fuel value [11], a necessary preliminary to capacity and operating cost determination.

The unit costs per ton of volatile matter destroyed afford perhaps the most descriptive and comparable figures for the results obtained in all plants, as a measure of work done.

Capital Costs

Comparison of Plant Construction Costs Difficult

The plant construction costs, Item 9, Table 1, are not comparable. Some of the reasons for this fact have been previously outlined. The same reasons given for the non-comparability of Item 11, total operating expense, also apply here.

Acquisition of data for various plants to obtain comparable investment costs either original or replacement, is difficult; however, these costs are given for the Minneapolis-Saint Paul plant. Such data provide current construction cost information and make possible total vestance comparisons for selection of the most economical type of installation for a particular sewage treatment objective.

Plant Construction Costs By Principal Divisions

The Minneapolis-Saint Paul Sanitary District normally reports costs allocated between some 23 departments; however, for the purpose of comparison between plants, these accounts have been combined into the following principal divisions:

I. Screenings and grit removal and disposal.

II. Chemical handling, feeding, and disinfection.

III. Flocculation, sedimentation, and scum removal and disposal.

IV. Sludge concentration and vacuum filtration.

V. Incineration and ash disposal.

The operating costs reported in Table 2 conform to these principal divisions. The capital costs, discussed presently, also conform to these principal divisions.

The original cost (construction, engineering, and overhead) of the Minneapolis-Saint Paul sewage treatment plant was $3,932,762.49. This cost, broken down into the previously described divisions, is shown in Table 3. Further, the EN-R Construction Cost Index at the time of construction in 1935-8 averaged 200. The cost of subsequent additions and subtractions is shown, as well as the replacement cost of each division, with the additions adjusted for the proper EN-R Construction Cost Index ratio at the time of change to a present cost (January 1957) with an EN-R Construction Cost Index of 700.

Construction Costs Per Unit of Capacity

Inspection of Table 2 will reveal a Minneapolis-Saint Paul incineration system capacity as follows:

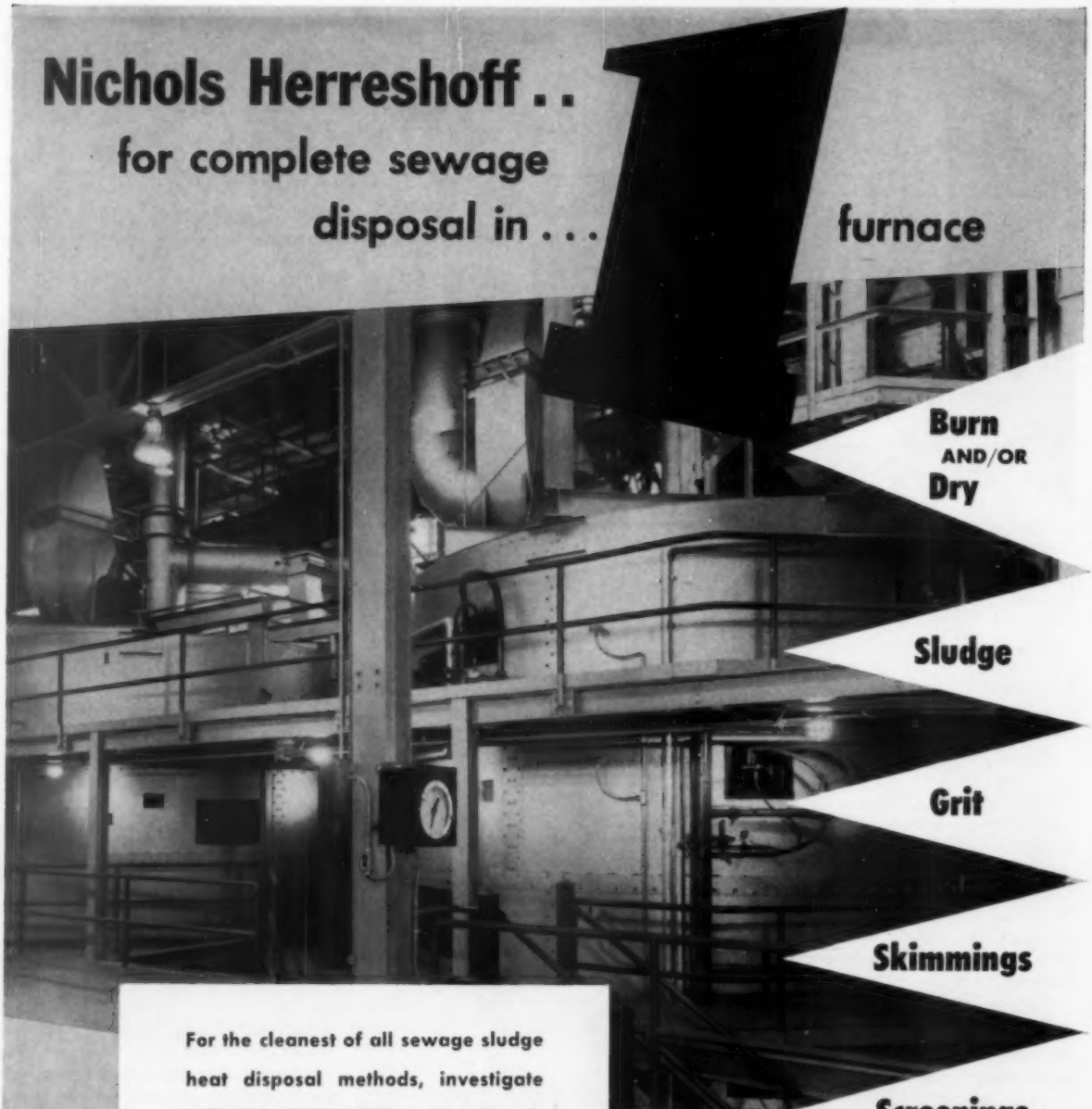
Dry solids per day.....300 tons
Combustible per day.....154 tons*
Water evaporation per day..576 tons*

*Simultaneously.

The figure given for capacity in terms of dry solids is, of course, affected by the moisture and combustible content of the cake, but the figure given may be considered as a "mechanical capacity"; that is, it repre-

Nichols Herreshoff..

for complete sewage disposal in . . . furnace



Burn AND/OR **Dry**

Sludge

Grit

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Screenings

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Table 2—Comparison of Sewage Solids Incineration and Associated Operating Total Disposal Cost Factors

Item No.	Item	Computation Reference	Unit	Buffalo [4] Fiscal Year 1955-1956	Cleveland [5] Calendar Year 1955 Southerly Only	Detroit [6] Fiscal Year 1955-1956	Mpls.-St. Paul [7] Calendar Year 1955
1.	Type of incinerators	.....		Gas & oil fired flash drier	Mult.-hearth (8 hearths)	Mult-hearth (11 hearths)	Mult.-hearth (8 hearths)
2.	No. of units installed	.....		3	4	4	4
3.	Cap. of each incin.:	.....			18'-9" dia.	22'-3" dia.	22'-3" dia.
4.	Dry solids per day	.....	Tons	30	25	110.1	75
5.	Combustible per day	.....	Dry tons	14.6	12.5	53.9	38.4
6.	Water evaporation per day	.....	Tons	70	75	189.9	144
7.	System capacity	.....		Three times unit cap.	Four times unit cap.	Four times unit cap.	Four times unit cap.
	Ultimate analysis of sludge cake, combustible basis:				Sludge (not cake)	Grab sample	
8.	Carbon	.....	%	Not avail.	64.34	65.57	55.00
9.	Hydrogen	.....	%	Not avail.	8.21	8.96	7.36
10.	Oxygen	.....	%	Not avail.	20.97	20.92	33.40
11.	Nitrogen	.....	%	Not avail.	4.30	3.40	3.09
12.	Sulfur	.....	%	Not avail.	2.18	1.15	1.15
13.	Total	.....	%	100	100	100	100
14.	Combustible, dry basis	.....	%	Not avail.	47.87	51.43	72.5
15.	Heat in Btu lb comb.	.....		10,325	12,156	12,900	10,000
	Vacuum filtration:						
16.	Vol. matter in cake	.....	Tons	3,079	6,381	36,571	31,358
17.	Cake produced	.....	Dry tons	7,242	16,684	71,089	44,475
	Incineration:						
18.	Operating days	.....		284	365	365	354
19.	Inc. system time load factor	.....	%	32.3	48.0	75	88
20.	Inc. unit comb. load factor	26/5	%	59.6	69.6	69.6	65
21.	Inc. unit water evap. load factor	27/6	%	47.0	79.2	69.5	66
22.	Inc. unit dry sol. load factor	.....	%	68.3	92.1	69.7	47.5
23.	Wet feed rate/hr./incin.	.....	Tons	2.22	3.39	8.70	5.43
24.	Dry solids in matl. incin.	.....	%	38.5	27.7	36.8	27.3
25.	Combustible in above	.....	%	42.5	38.2	48.9	70.5
26.	Comb. burned/incin. day	.....	Tons	8.7	8.7	37.6	25.1
27.	Water evap./incin. day	.....	Tons	32.9	59.4	132.0	94.8
28.	Fuel oil/wet ton burned	.....	Gal.	0	0.175	0.205	0.14
29.	Sludge gas/wet ton burned	.....	cu ft	7,020	588	0	0
30.	Material incinerated:			Digested sludge cake	Digested sludge cake	Grit, scum, raw sludge cake, some dig. sludge	Raw sludge cake only
31.	Wet solids, total	.....	Tons	18,885	58,165	229,211	162,630
32.	Dry solids, total	.....	Tons	7,242	16,137	84,290	44,441
33.	Volatile matter (comb.)	.....	Tons	3,079	6,172	41,234	31,335
34.	Water evaporated	.....	Tons	11,643	42,028	144,927	118,189
35.	Ash produced	.....	Tons	4,163	9,965	49,056	13,106
36.	Digestion (vol. converted to gas)	.....	Tons	3,289	14,985	2,520	0
37.	Vol. matter destroyed (dig. + incin.)	.....	Tons	6,368	21,157	43,754	31,335
	Dry sewage solids:						
38.	Converted to gas in dig.	.....	Tons	3,289	14,985	2,520	0
39.	Vacuum filtered	.....	Tons	5,515	12,508	64,839	44,126
40.	Incinerated	.....	Tons	5,515	12,051	78,041	44,094
41.	Total in sludge only	.....	Tons	8,804	27,493	67,359	44,126
42.	Total (38 + 39 + 40)	.....	Tons	8,804	27,493	80,561	44,126

sents roughly the quantity that can be physically handled in the system.

But the *economic vacuum* filter capability of the present filter installation (4,000 sq ft) will reduce the dry solids figure to about 240 tons per day for the over-all system. Using the over-all figures, the present installed sludge disposal construction costs per unit of capacity are approximately as follows:

$20,100 per ton of dry solids per day, or

$31,300 per ton of combustible destroyed per day, or

$8,370 per ton of water evaporation per day.

This is derived from the data in Table 3 (Item IV + V ÷ plant capacity in terms of dry solids, combustible, or water evaporation). This amounts to $4,820,000 ÷ plant capacity.

Vestance[1]

From Table 3, the total present replacement cost of the sludge disposal equipment including the building and other structures is $4,820,000. These fixed assets are divided approximately as follows: 50% equipment, 50% long-lived structures and apparatus. The former has been assigned a depreciation rate of 4%, or a life of 25 years; the latter has been assigned a depreciation rate of 1⅓%, or 75 years. This amounts to an over-all depreciation rate of about 2⅔%. An interest rate of 5% has been chosen for money costs and debt servicing.

Let

C = first cost;
n = life, in years;
R = interest rate = 0.05;
a = operating cost per year;
V = vestance, the total present cost of a permanent service = $V_d + V_o$;

$$T = \text{term factor} = \frac{(1+R)^n - 1}{(1+R)^n};$$

$$V_d = \text{depreciation vestance} = \frac{C}{T};$$

$$V_o = \text{operating vestance} = \frac{a}{R};$$

A = total annual cost = RV;
e = equipment; and
s = structures.

Substituting from Table 2, Item 58, and from Table 3, Items (IV+V)÷2.

Table 2 (Cont.) Comparison of Sewage Solids Incineration and Associated Operating Total Disposal Cost Factors

Item No.	Item	Computation Reference	Unit	Buffalo [4] Fiscal Year 1955-1956	Cleveland [5] Calendar Year 1955 Southerly Only	Detroit [6] Fiscal Year 1955-1956	Mpls.-St. Paul [7] Calendar Year 1955
	Direct proc. costs (Incl. maint.):						
43.	Digestion and conc.	.....	$	96,480.43	96,678.93	4,323.41	0
44.	Vacuum filt. and conc.	.....	$	68,325.41	207,374.03	221,932.14	171,266.98
45.	Inc. and ash disposal	.....	$	84,703.04	109,691.81	382,154.02	95,875.03
46.	Sum. direct proc. costs	.....	$	249,508.88	413,744.77	608,409.57	267,142.01
	Direct cost of proc. per ton of dry sew. sol.:						
47.	Converted to gas in dig.	43/38	$	29.33	6.45	1.72	0
48.	Vacuum filtered	44/39	$	12.39	16.58	3.42	3.88
49.	Inc. and ash disposed of	45/40	$	15.36	9.10	4.90	2.17
50.	Direct cost of disposal per ton of dry sludge sol. only	46/41	$	28.34	15.05	9.03	6.05
51.	Direct cost of disposal per ton of dry sew. sol. in 47, 48, 49	46/42	$	28.34	15.05	7.55	6.05
	Direct cost of proc. per ton of vol. matter:						
52.	Converted to gas	43/36	$	29.33	6.45	1.72	0
53.	In filter cake	44/16	$	22.19	32.50	6.07	5.46
54.	Incin. and ash disposed of	45/33	$	27.51	17.77	9.27	3.06
	Total process costs:						
55.	Digestion	.....	$	134,658.59	122,886.57	5,583.29	0
56.	Vacuum filtration	.....	$	96,959.03	263,588.80	286,605.23	331,654.97
57.	Incin. and ash disposal	.....	$	141,970.29	139,426.98	493,517.26	185,660.02
58.	Total disposal cost	.....	$	373,587.91	525,902.35	785,705.78	517,314.99
	Total cost of proc. per ton of dry sewage sol.:						
59.	Converted to gas	55/38	$	40.94	8.20	2.22	0
60.	Vacuum filtered	56/39	$	17.58	21.07	4.42	7.52
61.	Incin. and ash disposed of	57/40	$	25.74	11.57	6.32	4.21
62.	Total cost of disp. per ton of dry sewage sol. in 59, 60, 61	58/42	$	42.43	19.13	9.75	11.72
	Total cost of proc. per ton of vol. matter:						
63.	Converted to gas	55/36	$	40.94	8.20	2.22	0
64.	In filter cake	56/16	$	31.49	41.31	7.84	10.58
65.	Incin. and ash disposed of	57/33	$	46.11	22.59	11.97	5.93
66.	Direct cost of disp. per ton of vol. matter destroyed	46/37	$	39.18	19.56	13.91	8.53
67.	Total cost of disp. per ton of vol. matter destroyed	58/37	$	58.67	24.86	17.96	16.51

Disposal cost = sum of concentration + digestion + vacuum filtration + incineration + ash handling costs.

Note: Table does not include capital costs and depreciation. See Tables 3 and 4, as well as text, for a method of computing these items.

$$V_s = \frac{a}{R} = \frac{\$517,314.99}{0.05} = \$10,346,200.00$$

$$V_{d_c} = \frac{C_c}{T_m} = \frac{\$2,410,000.00}{0.52241} = \$\ 4,613,200.00$$

$$V_{d_s} = \frac{C_s}{T_m} = \frac{\$2,410,000.00}{0.97425} = \$\ 2,473,700.00$$

$$V = \$17,433,100.00$$

$$A = R\,V = 0.05 \times \$17,433,100 = \$871,655$$

Thus, the 1955 Minneapolis-Saint Paul District total unit sludge disposal costs were as follows:

$\frac{\$871,655}{44,126} = \$19.75$ cost/ton dry sewage solids

$\frac{\$871,655}{31,335} = \$27.82$ cost per ton of volatile matter destroyed

(See Items 42 and 37, Table 2.)

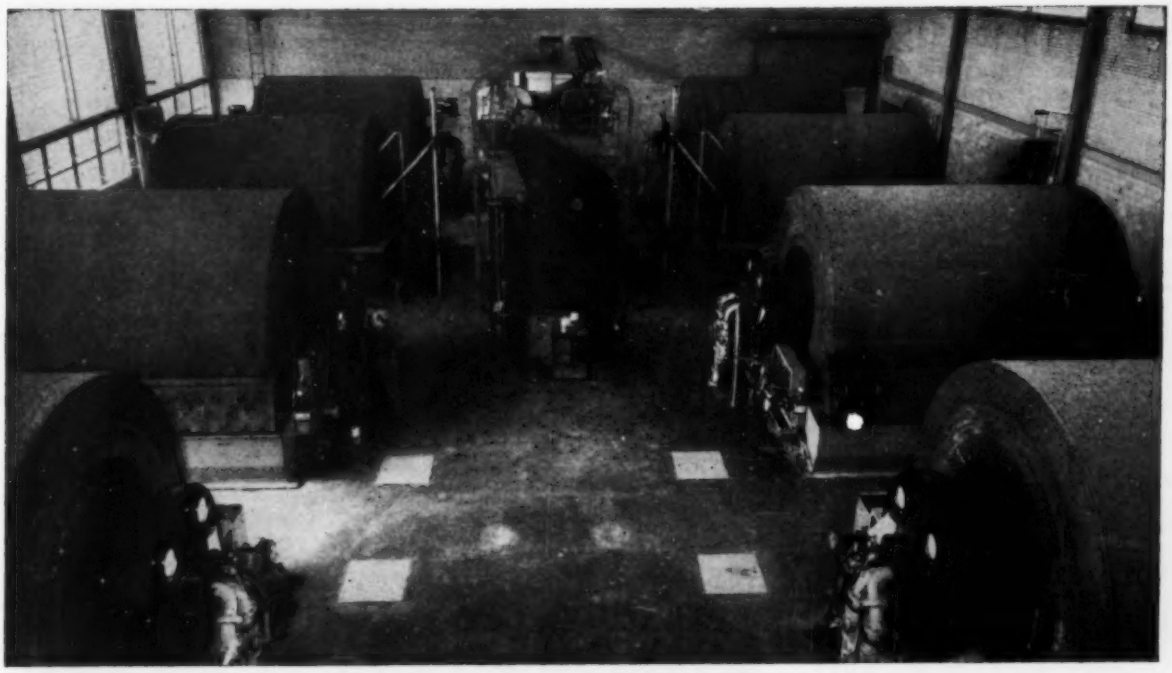
Conclusion and Discussion

The previous section is an examination of all solids disposal costs for a sewage treatment plant. The only factor which might not have been adequately considered is that of obsolescence, which is usually a somewhat unknown quantity.

The total unit sludge disposal costs for the Minneapolis-Saint Paul plant, previously computed under "Vestance," which give proper consideration to all facets of operating and capital costs, are considerably lower than those quoted for Cleveland and elsewhere by Wirts [3]. It would appear that this is due to utilization of the raw rather than the digested sludge process at Minneapolis-Saint Paul, plus low initial capital costs, as well as different methods of treating capital costs.

It appears that after the sewage treatment requirements in respect to degree of treatment have been determined for new sewage treatment plant facilities, either for an original plant or for the expansion of an old one, more comparative vestance [1] or capitalized[10] cost studies of various processes should be made before new construction is attempted.

The manner of operation of an incinerator system has an important effect on cost. Of prime importance is operator training, initiative, and the availability of an up-to-date set of operating instructions. No less impor-



EIGHT vacuum filters dewater sludge to cake for incinerator feed.

tant is the need for modern control and measurement apparatus and the associated equipment to carry out the changes indicated or required by the system controls. These factors are instrumental in obtaining maximum system capacity and, thus, minimum investment costs as well as minimum maintenance.

The burning of sewage solids is considerably different than burning a standard fuel. A standard fuel is much more uniform in characteristics and has a much more predictable behavior — not so with sewage solids. Table 2 shows that an enormous quantity of water must be evaporated compared to a standard fuel. This moisture is a factor that is somewhat controllable on a long-time interval basis in the vacuum filtration process, but from the standpoint of a quick short-time adjustment it is a practical impossibility. Further, due to the volatile matter present in the sludge cake, and particularly in the scum, there is a tendency for flash-over or rapidly rising temperatures to occur at or near the ideal combustion ratios in the combustion zone after the bulk of the water has been evaporated. This condition is controllable by the addition of excess air, maintenance of uniform feed, and cyclic and rate control of feed, as well as point of introduction.

The apparatus necessary to eliminate unusual bumps in load or temperature in the incineration system includes continuously weighing scales with recording of the totalizer reading every 15 minutes and computation of the feed input to each incinerator unit for this period. It includes continuously recording oxygen analyzers for each incinerator unit (preferably of the magnetic gas principle type) with a good sampling system.

Also vital to the process are multiple-point continuous recording pyrometers, and uniform control of draft and/or preheated air. Laboratory analyses of the filter cake and a load limit chart are made available to the operators. From a cost standpoint, the operating cost of the laboratory assignable to the principal divisions as previously described, are approximately as follows:

I = 12%
II = 0%
III = 51%
IV = 22%
V = 15%
} 37% sludge disposal

Total 100%

In connection with multiple-hearth

Table 3—Minneapolis-Saint Paul Sanitary District Sewage Treatment Plant Capital Costs

Cost Item	Description	Original Plant Cost	Original Cost Adjusted to Jan. 1, 1957	Sum of Present Value of Additions and Subtractions	Replacement Cost of Existing Plant	% of Total
Index	EN-R Construction Cost Index	200	700	700	700	
I	Screenings + grit removal + disposal	$ 484,442.04	$ 1,695,000	$— 31,000	$ 1,664,000	13.2
II	Chemical handling, feeding and disinfection	207,163.11	725,000	+ 2,000	727,000	5.8
III	Floc., sed., scum removal and disp.	1,897,789.46	6,640,000	—1,222,000	5,418,000	42.9
IV	Sludge conc. and vacuum filt.	580,201.41	2,030,000	+ 20,000	2,050,000	16.2
V	Incineration and ash disposal	763,346.47	2,670,000	+ 100,000	2,770,000	21.9
Total	Complete plant values	$3,932,762.49	$13,760,000	$—1,131,000	$12,629,000	100

type incinerators, variable central shaft speeds are of value, as well as certain limiting temperature controls. In the Minneapolis-Saint Paul system, the temperatures are limited in the hot zones to approximately 1600°F to protect the rabble arms and the central shaft. The rabble teeth and rabble arms are a ferrous alloy containing 25% chromium and 12% nickel. This is approximately equivalent to stainless steel type 309. A glance at a metallurgical table shows this metal will "creep" substantially starting at temperature of 1700°F and above.

To check this factor and reduce arm drooping, a thermocouple was installed in a Hearth 4 (hot zone) rabble arm approximately 16 inches from the inside end. This is a point of high stress and a point of hot flame application. Results to date (since April 1956) show that this thermocouple at times reads higher than the furnace peripheral thermocouples by as much at 200°F.

Of further interest in this particular system is the fact that conduction, convection, and radiation measurements at an incinerator feed rate of 1.4 tons of combustible per hour show a heat loss to the room of about 266,800 Btu's per hour per incinerator unit. In summer, several times as much air will be required for room ventilation compared to the total amount of fresh air required for combustion and excess air for incineration control purposes.

The limits of the evaporation and burning cycle can be better understood from the following 24-hour practical experience observed at Minneapolis-Saint Paul.

Ranges of sludge cake input conditions (from 24-hour composite samples):

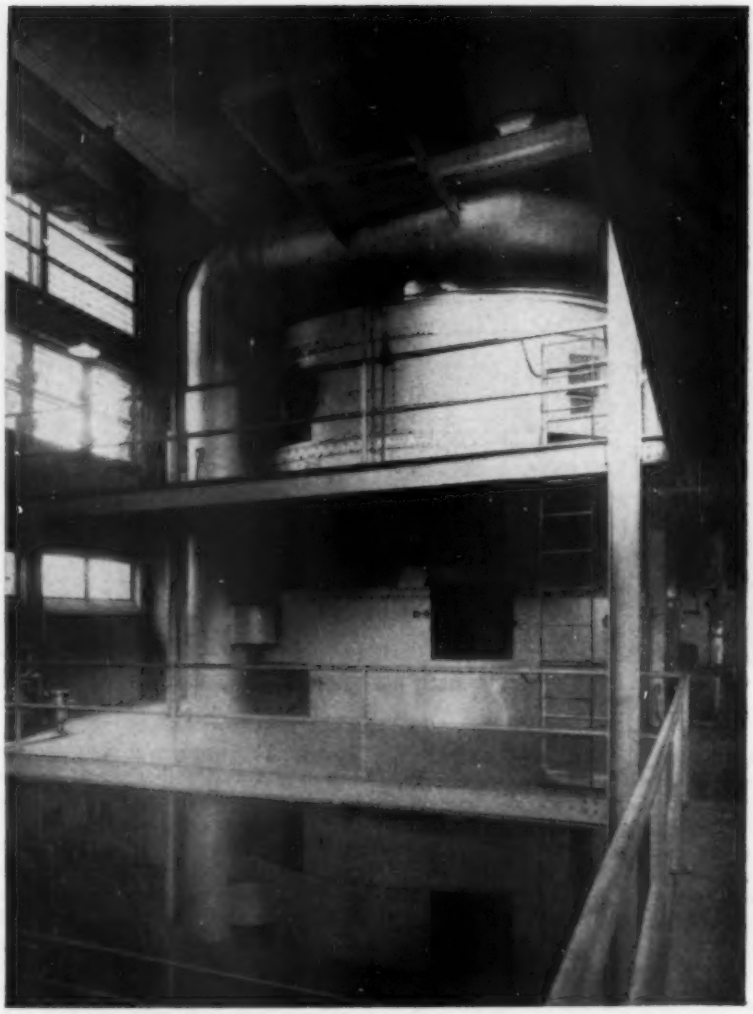
22.7% to 46.4% dry solids (Dec. 1956, June 1946)

35.5% to 83.2% combustible (dry basis) (May 1942, Feb. 1956).

Maximum and minimum heat input conditions observed were as follows:

31.5% solids with 75.0% combustible. (Dec. 1953) and

36.9% solids with 46.9% combustible (July 1944).



MULTIPLE-HEARTH incinerator is one of four in Twin Cities installation.

Table 4—Sludge Disposal Construction Costs*

Item No.	Item	Buffalo [4,12]	Cleveland [5,12]	Detroit [6]	Mpls.-St. Paul [7]
1.	Date of original construction	1939	1932-1936 W 1938 S	1936-1940	1935-1938
2.	Date of principal additions	1951	1951 S	1955	1951-1956
3.	Original cost, conc., filt. and incin. inv. only	$ 630,600	$ 686,071 W 2,807,000 S	$2,295,400	$1,343,367.88
4.	Cost of additions, conc., filt. and incin. inv. only	251,000	2,487,000 S	101,250	402,625.73
5.	Original cost: digestion inv. only	414,807	1,091,000 S	260,000	0
	Digestion Additions		2,019,102 S		
6.	Total	$1,296,407	$9,090,173	$2,656,650	$1,745,993.61
7.	Replacement cost of existing plant at EN-R Index of 700	Unknown	Unknown	Unknown	$4,820,000

* Total construction cost of digestion and gas handling equipment, concentration tanks, vacuum filtration equipment, incineration and ash handling equipment, including the buildings and all structures associated therewith.

† W and S refer to the Cleveland Westerly and Southerly plants, respectively.

TOP two hearths of eight-hearth incinerators, with flue breeching above.

11,600 Btu/lb combustible in the cake.
9,300 Btu/lb combustible in the cake.

Maximum and minimum amounts of material burned per 24 hours in one incinerator (computed to an hourly basis):

45.8 tons combustible (Aug. 1942) = 1.91 tons/hr
16.2 tons combustible (Nov. 1943) = 0.675 tons/hr
78.5 tons dry solids (May 1942) = 3.27 tons/hr
15.3 tons dry solids (Jan. 1945) = 0.637 tons/hr
191.1 tons wet cake (Dec. 1956) = 7.96 tons/hr
51.9 tons wet cake (Jan. 1945) = 2.16 tons/hr

Maximum and minimum tons cake water evaporated per 24 hours in one incinerator:

146.8 tons water (Dec. 1956) = 6.11 tons/hr
45.9 tons water (June 1944) = 1.91 tons/hr

The maximum 24-hour system loads observed have been as follows (4 incinerators operating):

677.5 tons wet cake (May 1956) = 28.1 tons/hr (no chemicals used)
182.2 tons dry solids (May 1956) = 7.58 tons/hr (no chemicals used)
126.1 tons combustible (May 1956) = 5.25 tons/hr (no chemicals used)
510.2 tons water evap. (May 1956) = 21.2 tons/hr (no chemicals used)

It must be remembered that none of these loads necessarily occurred simultaneously unless specifically so stated. However, simultaneous loads up to the capacity figures delineated in Table 2 are practical.

Accurate means of dividing feed between incineration units require belt system take-off blades, sludge cake levelers, shredders, or other means of segregating feed in order to obtain maximum capacity and flexibility of the incineration system. There are other factors, such as the ash disposal system, which affect cost of operation; but they are not as critical.

It must be kept in mind that the incinerator process must be considered as a system and the various components analyzed from the standpoint of their effect on the whole, in terms of operation and total cost.

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Sewage Sludge for Production of Topsoil

By ARTHUR J. SCANLON
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■ IN NEW YORK CITY, the idea of recovering organic sewage solids and returning them to the soil as fertilizer has been advocated since the early screening plants were built in Brooklyn and Queens. No significant progress was made in this direction until 1935, when the practice of separate sludge digestion was established at the Coney Island sewage treatment plant. Digestion not only produces an odorless sludge acceptable as a fertilizer or soil conditioner, but also yields a valuable product in the form of methane gas which is used for heat and power.

Topsoil Building

The first digested sludge from the Coney Island plant was used in 1936 on the plant grounds to stabilize the existing sand cover and produce a topsoil for lawn making. In December of that year, a larger load of digested sludge was taken about a mile to the proposed Marine Park recreational site, an area of approximately 725 acres, adjacent to Floyd Bennett Airport near the south end of Flatbush Ave. Approximately one-fourth of the area was suitable for the air drying of wet sludge. The remainder of the area was marginal and was to be used for a landfill operation.

The original Coney Island plant included facilities for dewatering the digested sludge by a vacuum filter with the thought that the sludge could be used as a fertilizer. However, operation of the vacuum filter was more costly than the air drying of sludge at Marine Park, and the filter operation was discontinued.

The New York City park and sanitation departments instituted an extensive sanitary landfill program for reclaiming marginal lands throughout the city. The final development of the landfill areas for recreational purposes depended on the securing, at reasonable cost, the topsoil required to sustain lawns, shrubs, and trees.

Two million cubic yards of topsoil were needed for covering 1,900 proposed acres throughout the city. This quantity of topsoil was not available within the city or in neighboring counties. The New York City Park Department, therefore, retained a landscape architect as a consultant to report on economical ways and means of making topsoil artificially. His investigation was not limited to the utilization of sewage sludge alone but included studies of other methods which might be successful in producing a topsoil. The consultant found that at Spring Creek Park, Queens; Marine Park, Brooklyn; and Great Kills Park, Staten Island, which have hydraulically pumped sand coverings, artificial topsoil could be created economically through the use of sewage sludge. These three sites comprised 1,400 acres of the 1,900 potential acres of reclaimed lands proposed for parks.

As a result of these studies, the Park Department consultant estimated that the artificial topsoil could be produced in place at a cost of $1,600 per acre by using sludge, as compared to $4,500 per acre for the buying and placing of natural topsoil. However, no allowance was made by the consultant for the delivery of the sludge to the park areas by the Department of Public Works, a cost chargeable to sewage disposal operations. The Department of Parks approved the recommendations of the consultant and in 1950 requested funds to initiate the program at Marine Park. The Department of Public Works asked that the program of sludge disposal in park areas be arranged so that it would not interfere with the disposal of sludge from the nine plants being serviced by the sludge vessels.

The operation at Marine Park has proven most satisfactory as far as cost, adequacy, and noninterference with sludge disposal at sea are concerned. The program has provided New York City with (a) a cheap method of disposing of digested sludge and, (b) a suitable, inexpensive topsoil from the organics in the sludge.

At Marine Park, a sludge pumping station was constructed on an abandoned dock in Mill Basin. Four positive displacement 350 gpm pumps are housed in the pumping station. The six cargo tanks on the sludge vessel are dewatered in 4 to 5 hr. through the use of flexible 6-in. hoses and aluminum deck and drop pipes. The dock site is separated from the park by Flatbush Ave., a heavily traversed road. Therefore, a 12-in cast iron pipe was laid under this thoroughfare to a manifold from which 6-in. diameter aluminum piping stretches out into the area being processed. Gasoline powered booster pumps having capacities of 400 gpm at 75 psi, were installed at critical points in the distribution system.

An area of approximately 40 acres is processed at one time. The sludge is sprayed through a 1½-in. diameter fire department deck-size nozzle. Each sprayer can apply the wet sludge at the rate of approximately 1 ga. per sq. ft. over an area 80 ft. in diameter. The sludge is allowed to dry for two or three days after which it is disked into the upper 9 in. of sand cover. The sludge spraying operation is repeated about 16 times to an area or until 4-in. of topsoil is formed from the sludge and sand.

In 1955, 18 sludge vessel trips were made to Mill Basin for sludge unloading. During 1956 a total of 110 trips were made. On a quantity basis, the volume disposed on land areas in this operation was more than 3,500,000 cu ft.

During 1956, 175 barge trips, carrying about 1,500,000 cu ft of wet sludge, were unloaded at Marine Park. The digested sludge was sprayed rather than pumped into drying beds as was done in previous years. In three different sludge bed areas located in the southwest, northeast, and southeast areas of the proposed park some 35,000,000 cu ft of wet sludge was dried between 1936 and 1955 .

During 1956, all the sludge was removed and placed on graded areas and disked into the sand cover to form topsoil. Most of the dried sludge was used on areas adjacent to avenues or highways where the spraying of sludge would be undesirable. On the easterly border of Marine Park an extensive strip adjacent to the avenue has been planted to grass, using the sludge from the first beds which were active up until 1948. On the north side of the Belt Parkway, which runs through Marine Park, the

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sludge from the last beds is being disked into the sand cover in preparation for grass seeding.

In 1956, 5,000,000 cu ft of sludge were sprayed on landfill areas. There are large areas that have been land filled and are ready for top dressing, and also other large areas which require landfill before top dressing can be added. This program will require many years and millions of cubic feet of sludge to complete.

Canarsie Pol

During 1956, another means for the disposing of sludge was provided and placed in operation at the 26th Ward plant. A 12-in. pipe line, submerged from the end of the sludge vessel loading line at the dock, was placed 6,000 ft. across the North Channel of Jamaica Bay to a high area known as Canarsie Pol. Canarsie Pol is a sandy barren area of about 250 acres, about 8 to 10 ft. above mean sea level. Access to the Pol is limited to very shallow draft vessels and then only at high water.

Conservationists of the United States Fish and Wildlife Service and the New York State Conservation Department were most desirous of developing this land for a bird sanctuary. Organic material was needed to sustain vegetation for feeding and sheltering the birds. Therefore, plans were made for the installation of a high-pressure pump and a pipe line to carry the sludge from the 26th Ward plant to the Pol.

During 1956, sludge vessels were not required. About one-half of the sludge removed from this plant (1,500,000 cu ft) was disposed of via the pipe line. This amount would have been greater were it not for pipe blockages and breakages during the year.

One very novel development in the operation at Canarsie Pol was the use of a helicopter. Because of the inaccessibility of the Pol, there were many days that the amount of sludge in the different lagoon areas could not be determined and additional pumping might have caused spilling of sludge over the lagoon berms into the waters of Jamaica Bay. The helicopter patrol of the New York City Police Department was requested on several occasions to report the situation on the Pol. Pumping operations were varied accordingly.

At the present time, there is a stockpile of about 10,000 cu yd of dried sludge removed from the 26th Ward sludge beds. All of this material will be transported to Marine Park where it will be used as topsoil for the border area adjacent to avenues and highways in much the same manner as the dried sludge from the beds at Marine Park. In previous years, the dried sludge at the 26th Ward plant was a source of supply of topsoil for landscaping projects of the Park Department and for use by the Department of Public Works for the landscaping of the Owls Head and the 26th Ward plants.

Cost of Operations

Robert F. Moses, Commissioner of Parks, has stated that natural topsoil for city parks would cost about $3.50 per cubic yard. However, the "ersatz topsoil" from digested sludge can be produced for $1.50 per yard. This difference means millions in the taxpayers' pockets, a matter of simple arithmetic.

The cost of $1.50 per cubic yard for making the ersatz topsoil does not include any charge for the transportation of the sludge to the dock or park area. As stated previously, disposal of sludge is normally charged to the sewage treatment operation. If the cost of transportation to the proposed park areas is less than the normal cost of sludge disposal at sea, then the city realizes an added saving. On the other hand, if this cost is more than the normal disposal cost, then an additional charge should be made for the ersatz topsoil.

In the analysis of whether there is any saving or an extra expense in making synthetic topsoil against buying topsoil, a comparison can be made with the normal cost of sludge disposal by vessels at sea. For the three-year period, 1953 to 1955, the cost of maintenance and operation of the four sludge vessels serving nine sewage treatment plants, together with the fixed charges, was $0.43 per wet ton and $9.31 per dry ton. Of this amount, maintenance and operation charges were $0.35 per wet ton and $7.60 per dry ton, respectively.

In the operation of the sludge vessels to the Marine Park dock, the trips required only one-half the mileage of those to sea. The services of the boat personnel were reduced further by the fact that unloading at Marine Park was restricted to the evening hours without the use of marine crews. Therefore, there was a saving of fuel oil consumption, wear on the propulsion engines, and personnel charges. This saving is estimated to be about 10 per cent of the cost of dumping the sludge at sea.

Pumping from the 26th Ward plant to the Canarsie Pol is a negligible additional operating cost since pumping has to be done in any event either to the beds or to sludge vessels. The fixed charges for the pump and pipe line are estimated at $0.12 per wet ton. While the fixed charges are $0.04 per wet ton more than the fixed charges for the sludge vessels, the operating and maintenance charges are negligible as compared to the cost of $0.35 per wet ton in the case of the vessels. With this appreciable saving, the cost of sludge disposal from the 26th Ward plant to the Canarsie Pol is about one-quarter of the cost of sludge disposal using vessels.

At the Coney Island plant the cost of these two new methods is approximately 25 per cent less than the normal cost of sludge disposal at sea. This saving may be added to the $2.00 per yard saved using sludge for topsoil. The total saving realized by the city through this operation is about $2.50 per yard. With the expected use of approximately 400,000 cu yd of ersatz topsoil in Marine Park the saving to the city as compared with natural topsoil will approach the $1,000,000 mark.

The final criterion of an efficient operation of this process is to have no interference with the conventional disposal of sludge to sea. This criterion too, is more than met. In 1956 the sludge vessels made a total of 1,250 trips, more trips than were made in any previous year since the last four treatment plants were placed in operation in 1952. As a matter of fact, there was a 10 per cent increase in 1956 in the number of trips and the amount of sludge carried compared to 1955.

Experience has shown that where distances are not excessive, pumps and pipe lines are the most economical method of transporting sludge.

Summary

A new method of sludge disposal, supplementing disposal at sea, is now being employed by the City of New York. The Department of Public Works transports digested sludge to proposed park sites. The Park Department removes the sludge from the boats and produces artificial topsoil at the sites.

The city realizes a substantial saving by creating this artificial topsoil. This saving is twofold: (a) transportation charges to the park site are less than sea disposal charges, and (b) handling and processing charges at the park sites are much less than the cost of natural topsoil.

Aside from these tangible savings, the most important consideration is that the digested sludge used in making ersatz topsoil provides the solution to the problem of obtaining natural topsoil which is not available in large quantities locally.

Sewer System Maintenance

by JAMES B. SMITH

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SEWER SYSTEM Maintenance is used here to mean the performance of those functions necessary for the operation and maintenance of the entire sewerage system and all of the component parts thereof. The term is used to include preventive maintenance, repair maintenance, routine operation, the keeping of repair records and cost data, as well as the creation and development of proper public relations in the community.

A study of 45 sewer systems throughout the State of Louisiana has been made in regards to the type of municipal government, the people of the community, operating personnel, type of organization, availability of financial support, and a number of other lesser factors.

Government and the People

Information was obtained in discussions with City officials, the City Clerk, and others familiar with the operations of each municipality in order to determine:

1. The type of government and the place of the sewer maintenance organization therein;
2. The attitude of officials and their knowledge relative to the sewer system and its maintenance;
3. The attitude of the people of the community, their knowledge of the sewer system, and their willingness to provide financial support.

Type of Government

The type of government and its relationship to maintenance is shown in Table 1.

The government of the municipality is beyond the scope of this study and beyond the control of the operator. However, it is interesting to note that the type of government has some bearing upon the maintenance of the sewer system. The commission form of government accounts for a higher percentage of *Excellent* conditions, and the mayor and council form of government accounts for a higher percentage of *poor* conditions. The separate sewerage board may provide the best maintenance; however, the information available is insufficient for definite conclusions.

It is also to be noted that *Excellent* maintenance is attainable under all of the forms of government, and that *Poor* maintenance is also found under each of the two generally used forms of government. Whereas the type of government has some bearing upon the maintenance of the system, there are other factors of much more importance.

Attitude and Knowledge of the Officials

Information on the attitude of officials and their knowledge of the system is summarized in Table 2.

As is evident in Table 2, the attitude of the officials and their knowledge of conditions relative to the sewer system and its maintenance are two of the most important factors affecting maintenance.

Many officials were encountered who were sufficiently interested in the system, but were unable to evaluate the conditions as found. In several such cases there was evidence leading to the conclusion that the official was being intentionally misled and misinformed as to the existence of unsatisfactory conditions.

In approximately 30 percent of the municipalities it was found that the officials were not sufficiently interested in the sewer system and its maintenance to warrant their visiting the plant, pumping stations, or other facilities. However, in the remaining 70 percent of the municipalities, a genuine interest on the part of the officials prevails, and in those cities the officials are fairly well informed.

Attitude and Knowledge of the People

The attitude of the people of the community, their knowledge of the sewer system, and their willingness to give financial support are factors which were extremely difficult to ascertain. However, in the people of the community rest the most important factors affecting maintenance.

TABLE 1

Type of Government	Condition of Sewer System			
	Excellent	Good	Fair	Poor
Separate Sewerage Board (1)	100%			
Mayor and Commissioners	43%	14	14	29
Mayor and Councilmen	25%	22	15	41

TABLE 2

Attitude and Knowledge of Officials	Condition of Sewer System			
	Excellent	Good	Fair	Poor
Proper Attitude and Sufficient Knowledge	43%	22	35	0
Improper Attitude and Insufficient Knowledge	0%	20	20	60

The people of the community are the ones who are able to provide adequate facilities; the people of the community are the ones who are able to provide sufficient financial support for proper operation of the facilities.

As evidenced by questions among the city employees—the people most likely to know about the sewer system—it was found that, in general, the people of the community have very little knowledge of the sewer system and the problems of operating personnel. As evidenced by the bond issues that the voters have approved in recent years for improvements and extensions, it is apparent that, when intelligently informed of conditions, the people will provide funds for the construction of suitable facilities and for the maintenance of the system.

Operating Personnel

Discussions were held with operators and operating personnel in order to determine:

1. The knowledge and experience of the personnel;
2. Their attitude towards their work and their system;
3. The organization within which they operate.

Knowledge and Experience of Personnel

The knowledge and experience of personnel were found to be excellent in all but a few isolated cases. The superintendents, operators and permanent laborers, in general, have a very thorough knowledge of the work they are doing. The degree to which this knowledge extends was found to be dependent upon the extent of the facilities being operated. However, the knowledge of personnel in regards to the keeping of records, cost data and other information relative to the overall operation of the system was found to be lacking in far too many instances.

Attitude of Personnel

The attitude of personnel toward their work and their system was found to be as follows:

Excellent	37%
Good	27%
Fair	16%
Poor	20%

A correlation of the attitude of personnel and the condition of the maintenance of the system shows a direct relationship between the two factors. Proper attitude of personnel generally resulted in *excellent* or *good* conditions; improper attitude of personnel generally resulted in *fair* or *poor* conditions. In a number of instances, however, proper attitude of personnel was overcome or subdued by an inadequate system, insufficient maintenance funds, or political interference.

TABLE 3

Type of Organization	Condition of Sewer System			
	Excellent	Good	Fair	Poor
Sewer Maintenance Combined with Other Utilities	6%	17	60	17
Separate Sewer Maintenance	56%	25	13	6
Agreements with Plumbers	—	—	50	50

The Organization

The organization within which personnel operated was found to be as diversified as the municipalities themselves. In 50 per cent of the cities, the maintenance of the sewer system is combined with other utilities; in 43 per cent of the cities maintenance of the sewer system is performed by a separate organization; and in 7 per cent of the cities maintenance is performed through working agreements with local plumbers.

The condition of the sewer system relative to the type of organization is shown in Table 3.

It is clearly evident from Table 3 that a separate organization is the best method of obtaining satisfactory maintenance of the sewer system.

Cost Data

Data were obtained from the various City Clerks, or other appropriate official, as to:

1. The availibility of cost data;
2. The completeness and clarity of cost data;
3. The amount of expenditures for sewer maintenance.

Availability of Cost Data

It was found that 50 per cent of the municipalities keep records of cost of sewer maintenance. The remaining cities combine sewer costs with water, gas, streets, or other accounts. Of the cities keeping separate cost data, 50% do not separate the maintenance costs from the costs of making extensions to the system.

Completeness and Clarity of Cost Data

Of those municipalities with separate cost data, the vast majority were found to have fairly complete records. However, the method of breaking down the costs was found to be as diversified as the accountants who audit the cities' books. Consequently, the accounts have been set up primarily for the checking of funds, rather than for the comparison of costs with the results of operation and maintenance.

Expenditures for maintenance of the sewer system have been calculated on the basis of cost per capita annually.

Three all-gravity systems in towns of approximately 2500 population are being operated at a cost varying from nothing to 30 cents per capita annually.

In the cities requiring pumping and/or treatment of the sewage, some slight variation in costs resulted, depending upon the amount of pumping, the number and sizes of stations, and the type and degree of treatment. However, in general, costs of maintenance varied from $1.00 to $2.10 per capita annually.

Excellent conditions exist in those cities spending $1.50 to $2.10 per capita annually.

Good or *fair* conditions exist in those cities spending $1.00 to $1.50 per capita annually.

One city spends $2.00 per capita annually yet receives poor maintenance. However, such conditions are due primarily to faulty design and construction, an overloaded system, improper organization, and operating personnel having none of the technical knowledge required by the situation.

Of the cities studied, 50 per cent collect a monthly service charge; 20 per cent are in the process of starting the collection of such a charge; the remaining 30 per cent depend upon other means of financing operation of the system.

A great majority of the cities spending $1.00 or more per capita annually have in effect a monthly service charge. All of the cities spending less than $1.00 per capita annually obtain funds from other sources.

A direct relationship exists between the amount spent for maintenance and the manner in which funds are obtained, with the monthly service charge giving the best results in all cities using such method.

Inspection

A study of the sewer systems was made relative to:

1. Design;
2. Construction;
3. Maintenance.

Design

The study and inspection of the systems reveal a great need for improvements in the design of such facilities. Many of the operators' troubles are the direct result of inadequate design, and failure on the part of the engineer to consider the operation and maintenance of the component parts of the facilities. Following are listed some of the deficiencies noted:

1. Placement of bar screens and baskets in inaccessible locations;
2. Improper illumination, or complete absence of illumination, in pump pits and other locations requiring maintenance of equipment;
3. Improper ventilation of wet wells, pump pits, and other locations where the collection of odors and gases is likely;
4. Installation of equipment in inaccessible locations;
5. Omission of grit chambers preceding treatment plant equipment;
6. Use of delicate and complicated pump control equipment and flow indicating and recording equipment instead of simple, rugged and easy-to-maintain types;
7. Omission of fencing where necessary for the protection of the plant, equipment and the public;
8. Omission of floodlighting necessary for night operation and maintenance; and
9. Omission of painting of pumping stations and treatment plants.

Construction

Poor construction of sewer system facilities by the contractor as a result of the lack of, or complete absence of, proper inspection during construction was found to account for many of the problems confronting the operator.

Eighty percent of the systems have excessive infiltration due to faulty joints in the lines.

Thirty per cent of the systems have excessive amounts of sand getting into the lines and into the treatment plant.

Maintenance

The maintenance of the systems inspected was judged as follows:

Excellent	30%
Good	20%
Fair	36%
Poor	14%

Better Maintenance

In view of the foregoing, what can the individual superintendent or operator do in order to better the maintenance of his sewer system?

1. Analyze your own situation, the quality of your own maintenance, the type of government of your municipality, the attitude and interest in the system on the part of the officials and the people of the community. Analyze the knowledge, experience and attitude of your personnel and of yourself. Study your organization, its place in the organization of the city government, and its place in the community. Analyze your method of keeping records, of keeping cost data pertaining to operations, and the amount your maintenance is costing annually per capita. Check on the design and construction of your system. If already constructed, study possible methods of correcting deficiencies in design and construction. If under construction, correct the deficiencies before it is too late;

2. Visit other plants. Disuss your sewer maintenance problems with other operators. Compare your maintenance with the others;

3. Broaden your knowledge of your system in order that you may, in turn, broaden the knowledge of the officials and the people of your community;

4. Never overlook an opportunity to enlighten the people of the community in regards to the sewer system. Your greatest help and assistance may be derived from an educated and informed public;

5. Have the officials subscribe to one or two of the sewerage works journals. By the reading of such literature you and your personnel will become better informed;

6. If your maintenance organization is presently combined with other utilities, separate them;

7. Work with your City Clerk in order to set up a method of keeping the cost data on your maintenance. If such cost data are presently combined with other utilities, have them separated;

8. If your maintenance costs are presently combined with the cost of making extensions and other improvements to capital investment, have them kept separately;

9. If your municipality presently has no monthly sewer service charge, start working toward the securing of such a charge;

10. Set a goal on the amount of funds to be budgeted and used for the maintenance of the system. Generally, $2.00 per capita annually will do for a start. Work to obtain that amount;

11. Check the design of all new facilities with the consulting engineer before the bids are to be received. Then check on the construction of the facilities with the engineer as the work is in progress;

12. Conduct a cleanup and paint-up campaign for your treatment plant and pumping stations. Clean facilities are well maintained facilities.

When all of the foregoing has been accomplished, you and your personnel will have made your system one of which you can be justly proud.

Odor Control in Sewage Treatment

by THEODORE JAFFE

Professor of Civil Engineering, Alabama Polytechnic Institute, Auburn, Ala.

ONE OF THE most troublesome problems facing the operator of a sewage treatment plant is that of odors. This is a difficult one to solve because there is no universal corrective that will fit every situation.

Odors may be pleasant as those from a boiling steak; or, they may be unpleasant as from rotten eggs or decayed cabbage. In either case our noses, through which we receive odors, react in similar manner. It is only when the message from the smell organs in our nose reach the brain is there any pleasantness or unpleasantness attached to the odor. We have often heard the expression, "What is one man's meat is another's poison". So it is with odors; what may be pleasing to some people, is unpleasant (or worse) to others. In some cases we call an odor pleasing because we connect it with some long past pleasant event. These associations lead to one common type of complaint regarding sewage treatment plants — psychological odors. There are some persons who immediately associate the word sewage with filth and unmentionables, and will "smell" a treatment plant miles away whether or not odors actually exist. These types of complaints are the most difficult, if not impossible, to eliminate because they are not based on fact, but on imagination.

Aside from these psychological complaints, we all know that sewage treatment plants and sewage collection systems can be smelly at times. Depending on the intensity and duration of the odor, type of gas causing the smell, origin of the odor, atmospheric conditions, and other factors any of the following problems may arise:

1. Public relations difficulties
2. Damage to structures
3. Danger to persons
4. Poor efficiency
5. Personnel problems in the plant
6. Legal action

Public Relations

We have already discussed the psychological complainers, and will say no more about this type of person. However, most persons are reasonable and if they can be shown that their sewage treatment plant (which they pay for) is not a smelly, dirty place but rather a clean, well-operated facility, they will more likely take pride in it. They will see a pleasing return for their public health dollars, and will be more favorably inclined to the personnel operating the plant. This leads to better jobs, higher salaries, and greater personal satisfaction.

On the other hand, if the plant does give off unpleasant odors, the public will not take this without complaining—and rightly so. The superintendent will meet opposition in his requests, the taxpayers will keep his phone ringing, he will be after his assistants, and so on down the line, with everyone dissatisfied. Those of you operators who have serious odor problems are well enough aware of the public relations angles not to need any further discussion; those who are "on top" of the odor problem, keep up the good work.

Damage to Structures

Probably the most destructive of the gases that may be produced from sewage is hydrogen sulfide. It is a double-barrelled enemy, being not only harmful to structures but deadly to man. Most plant operators and many sewers maintenance men have seen evidence of concrete corrosion caused by hydrogen sulfide gas. How does this occur?

When sewage becomes septic, i.e. there is no dissolved oxygen present and active decomposition has started, the bacteria begin to break down mineral sulphates to obtain the oxygen of the SO_4 ion. One of the results of this bacterial action is the production of hydrogen sulfide (H_2S) as a by-product. Being a gas, it escapes readily into the air, causing the "rotten-egg" smell of hydrogen sulfide. Of course the rate of sewage breakdown, and the amount of sulfide held in the sewage depend upon the temperature. The warmer the temperature the faster the rate of breakdown, and the less gas that can be held in solution. Other factors also influence this situation for example, rate of flow, make-up of the sewage, pH, etc.

The hydrogen sulfide, by itself, would not harm concrete, manhole steps, lids, etc. However, with the assistance of sewage bacteria, the sulphur unites with water and oxygen to form sulfuric acid, and this strong acid attacks concrete. Actually the attack appears to be against the cement used in the concrete. The sulfuric acids tends to dissolve out the calcium of the cement and thus weaken the concrete. In sewers as well as at the treatment plant these have a "smell". Sewage, even when fresh, smells. But it is not "stinking". Since sewage does have an odor, various parts of a treatment plant are bound to have some odor. For example, there are odors around digesters, screenings have odors; sludge holding tanks have odors; all these cannot be eliminated, but they can be reduced or kept to a minimum. At the Wards Island, N. Y. sewage treatment plant sludge is finally disposed of by dumping in the ocean. This necessitates sludge storage facilities to hold the sludge till the vessels can transport it. These storage facilities are liable to produce odors which require attention, but they are normal to this type of operation and are controlled.

Odor Control

As can easily be seen from the previous discussion, odor control is a complicated problem and may be a costly one. The first approach in at-

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tacking this nuisance is to determine the source and the cause of the odor —is it the collection system and where in this system; is it an industrial waste and which one; is it in the treatment plant and where.

Having located the source, the next step is the identification of the odor —is it hydrogen sulfide, one of the protein breakdown gases, or possibly some solvent from a chemical manufacturing plant. Finally, what is the cause of the odor and what can be done about it.

When the above information has been obtained we are forced to make a decision as to which of all the possible treatments may be the correct one for the special problem at a particular plant or in a particular collection system. We cannot, in this article, give sure-fire answers to any particular problem; at best we can suggest possible solutions and rely on the plant operator's "horse-sense" and ingenuity to fit the solution to his special problem.

In view of the possible sources listed in a previous section and some of those to be found in the literature, the following remedies are suggested:

1. Good housekeeping and good operation. One of the simplest means of keeping odors to a minimum is frequent hosing down of all structures in a sewage treatment plant. Keep the sewers cleaned and pump sumps free of accumulating solids. Don't wait till spills have had a chance to produce smells, but wash down immediately. Set up a regular schedule, with a check sheet, for routine washing of all units. Place drains or sinks where needed, e.g. any sludge digester sampling lines should open over a sink or drain. Do not allow them to drip onto a table top or on the floor. The areas around screening dewatering or grit removers should be thoroughly washed down to a drain. Most any operator can find many such places in his plant where odors can "breed" if not properly cared for.

2. Segregation or pretreatment of obnoxious industrial wastes. This is not a simple job, but may need to be done in some instances. Cooperation on the part of industry is required. Some wastes are better treated at the industrial site; with others some degree of pretreatment at the site will eliminate or reduce potential odors. These problems require tact, resourcefulness, and sound reasoning on the operator's part to persuade industry to cooperate.

3. Mechanical methods. Where odors are produced in sewer lines, at manholes, etc., mechanical means of removing some of the odor promoting factors may be effective. Methods of this type include a routine sewer cleaning schedule to remove deposits and excessive slime growths, blowing air into sewers and lines, the use of special types of pipe, flush tanks on long lines with flat grades and small flows, etc. Of course some of these problems may be due to a faulty, original design of the lines, but the plant operator can do nothing about this after the system is in place. More ideas can be found in articles by Pomeroy[4] and Schneider[5].

Another approach to the odor problem by mechanical means is the use of ventilating or exhaust devices, and absorption or solution towers. Blowers are used to safe-guard the air in manholes when it is necessary to enter them. At the treatment plant some form of exhaust system may be of use. All systems of this type rely on the dilution of the objectionable odors with the atmosphere. The gases are withdrawn from the production site, sent up a tower or stack, and exhausted to the atmosphere. Great care should be exercised, and a careful study of meteorological conditions made, before adopting this method. If not, concentrations of odors may be produced, and the problem may be increased instead of eliminated.

Where scrubbers or solution towers are used, a collection system similar to the above is also required. However, instead of exhausting the gases to the atmosphere they are either taken into solution with a liquid (usually water), or oxidized chemically with chlorine, ozone, or similar products into non-smelly compounds. Do not fail to note that if the gases are taken into solution, some disposal of the liquid must be made.

The Pittsburgh, Pa. sewage treatment plant uses a heat treatment method to concentrate its primary sludge. In this heat treatment, odors are produced. The process is carried out in a closed system and the gases are led into the sludge incinerator where they are burned. It is claimed that the stack gases will not be obnoxious[6].

4. Chemical methods. Odor problems are often attacked by chemical agents. These generally fall into two types—(a) masking agents and (b) counter-actants.

Masking agents usually do not remove the causes of odors nor do they permanently rid the system of odors. They are a form of temporary treatment and are only effective as long as they are in use. This means a continuing, extra cost; and since they do not eliminate the cause, do not really solve the problem. In these respects they are least desirable as a solution to such difficulties. Most of these products only seek to cover up an unpleasant smell with a more pleasing one. However, in emergencies these deodorant products have provided relief and improved public relations—especially when experiencing hot and muggy evenings and nights.

Counteractants on the other hand, actually attack odors and by chemical means seek to change obnoxious odors and compounds into something else that is not unpleasant. Oxidation of gases by oxygen, chlorine, and other similar chemicals are examples of this type. While these counteractants do permanently dispose of the unpleasant odors, they too are temporary measures in that they are only effective as long as they are used. Some types claim to eventually eliminate odors by removing a cause of odor production. For example some of the chemicals used in up-sewer odor control claim that the compounds will attack and eliminate slime growths in sewers, and when the slimes (in which the bacteria live) are gone odors will cease.

To summarize the various odor control measures, we have temporary control procedures which, while effective to some extent, do not get at the basic problem. There are some types of counteractants which are useful as temporary means of control; others which have a somewhat permanent place because of inherent odors connected with some treatment processes.

However, it is this author's opinion that, by determining the location conditions may exist and cause odor problems.

Hydrogen sulfide will not only cause damage to concrete structures, but will also discolor painted tanks and buildings. This is another annoyance to the plant operator, and under certain conditions may affect buildings near the treatment plant site. Neighboring taxpayers do not care for this!

Structures may also be damaged by other gases resulting from the breakdown of organic matter in sewage. The decomposition of the organic substances may be controlled as in a digester, or uncontrolled as in faulty manholes or sagging sewer lines. In any case, when sewage solids settle out and anaerobic conditions prevail, decomposition will take place with resultant odors. One of the gases produced is methane, which although odorless, can produce violet explosions when in contact with air and a flame or spark. The literature has numerous references to explosions and damages caused by these breakdown gases.[1,2]

Danger to Persons

As mentioned previously, hydrogen sulfide can kill. It is a subtle killer, and not much is required; short exposures to low concentrations can kill (30 min, 0.1% by volume)[3]. If smaller doses are breathed, violent headaches and nausea may result.

An explosion resulting from methane in sewer or digester gas may kill or injure workers. Other horribly smelly gases resulting from protein breakdown will cause nausea when in very small concentrations, even though they may not kill.

However since odors are brought to our noses (and thereby to our attention) in the form of gases, any sewage plant worker noticing any unusual or unusually strong odors should be careful and investigate the source. It may be a poisonous or hazardous gas.

Efficiency and Personnel Problems

The presence of obnoxious odors around a treatment plant makes for inefficiency and creates personnel problems. No one cares to work in a smelly place. If a worker has to stay in a pit or sump that is evil smelling to do a repair job, it is half-bad. When he has to spend a full working day in such an environment, he becomes discontent, slip-shod, and unhappy—if not actually sick. He is not content to stay with the job, resulting in an unnecessary turn-over of personnel. With personnel so difficult to obtain, all superintendents should be concerned with odors for this, if for no other, reason.

Legal Responsibility

There have been instances where the courts have said that unreasonable odors from sewage plants must be done away with, and they have definitely acted against industry in many odor nuisance situations. Industrial wastes are especially liable to cause odors. The author knows of several situations where the courts have given a processor or manufacturer a fixed period of time within which the odors from waste disposal had to be eliminated. Usually court action is a last resort, but with the public's attention being focussed on air polution, it may be anticipated that more complaints regarding odors will be forthcoming.

Sources of Odors

Odors from sewage treatment plants may arise in five general ways:

(1) Septic sewage

(2) Some types of industrial wastes

(3) Plant operation

(4) Design problems

(5) "Normal" odors

Septic sewage will cause odors all along the collection system and in many parts of the treatment plant. Where long collection lines, low flows, and warm temperatures are found, odors will usually be present. If the topography of the community is flat, and the system is old, odors will usually be a problem. These may be strong enough to cause complaints around manholes, pumping stations, or the treatment plant. When the raw sewage entering a treatment plant is smelly, the plant operator's problem is increased, because many of the treatment processes either increase the septicity or bring out the odors more strongly, before reducing their intensity.

Some types of industrial wastes are especially liable to produce unpleasant odors either in the sewer lines or at the treatment plant. With industrial wastes, odors may be caused by the waste itself, or they may be caused by a non-smelly waste combining with another waste to form an unpleasant one. Some types of industrial wastes likely to produce odors are those from the chemical and pharmaceutical industry, packing houses, paper and pulp, coke and gas manufactures, etc. Dangerous wastes are those from the metal industries, gasoline and service stations, and some chemical wastes.

One of the common causes of odors is often to be found at the treatment plant. An unclean, poorly operated plant will be smelly and unpleasant. One of the surest ways to produce odors is sloppy plant operation, and this is one thing the operator cannot blame on the designer. It cannot be stated too strongly, that the first step in plant odor control is good housekeeping.

There are many instances where poor operation results from poor design, but most times it is up to the plant operator to reduce this difficulty to a minimum. To cite one example from the author's experience, a treatment plant was designed with chemical conditioning and vacuum filtration of raw, primary sludge. To secure sufficient sludge for economical operation, two open holding tanks were provided between the primary sedimentation tank and the filtration arrangements. While the design may be questionable, the operational procedure made matters worse. The raw primary sludge was drawn into the holding tanks, conditioned, and filtered in a reasonable time all through the week until Friday. Then, from about noon Friday till about 8 A. M. Monday the sludge was kept in the open holding tanks without any further treatment. Need we say that this plant had an odor problem?

The design of treatment plants is often faulty. Some of these faults are caused by the "nature of the beast"; some of them are just plain foolishness, or worse, on the designer's part. It is admittedly difficult to design a grit chamber or sedimentation tank or other units that will work perfectly at all the daily fluctuating flow rates and will also work at the present per capita flow as well as the predicted future flow. Similarly it is difficult to keep velocities in sewers at an estimated rate of flow under the many variables. These are situations which may lead to odor problems that are understandable even though they may be difficult to solve.

However, if a designer puts an open, shallow surge tank or a preaeration unit at the head of a plant receiving sewage that is already septic, he will be giving the operator odor problems. On exposing the sewage to the atmosphere or by blowing air through it, the odorous gases will be released and may, due to atmospheric conditions, concentrate in such amounts as to cause complaints. This exposure to air is actually used in water treatment plants to remove entrapped odors from water supplies.

All this discussion of odors does mean that a treatment plant will not and cause of a sewage odor problem, and then with a little study plus some plain old "horse sense," most situations can be controlled. Remember too, that the first essential for odor control in a treatment plant is good housekeeping.

The next article in this series will discuss the so-called "Package Treatment Plants".

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Sewage Plant Operation Tips

by ROBERT E. SIMON

Superintendent, Sewage Treatment Plant, Orlando, Fla.

THERE ARE MANY little things that can be done around the sewage treatment plant and lift stations that will help make operating easier and increase the chances of the superintendent getting a full night's untroubled sleep. At the Orlando, Florida sewage treatment plant a number of innovations were developed to ease the load on the operating personnel.

Lift Station Failure Alarm

One of the best additions to the overall maintenance setup is an electric failure alarm serving four of the largest lift stations. Even though automatic stand-by pump units have been provided in these stations, and are tested each day to make sure they are operating properly, there is always a chance that after the gasoline engines have stopped and started a number of times they may become vapor bound or flooded. It happens more frequently with the larger engines.

Telephone lines have been connected between each of the four main lift stations and the sewage treatment plant. To these lines a normally open relay is installed in the electric control circuit for the gasoline engine at the lift station. At the treatment plant a few low resistance D.C. relays have been installed to operate 110-v. A.C. relays in the alarm system. To distinguish which station is in need of attention, a different colored light was installed for each lift station. However, only one claxon was installed for the control board. A silencing button and an automatic reset are provided for controlling the horn. The only unsatisfactory feature in this arrangement is that if a power failure occurs at one lift station and the claxon is turned off, it is necessary to watch the lights on the control board to detect a power failure at another lift station. The claxon will not reset automatically until all the lift stations are cleared.

Daily testing of the alarm system by the lift station maintenance personnel is standard operating procedure. A predetermined signal is used so the treatment plant operator can distinguish between testing and a power failure. This system was designed, built and installed by plant personnel and it has paid for itself many times in facilitating lift station operation.

Radio Equipment

Another nice addition was the installation of two-way radio equipment in all the sewage treatment plant service vehicles. Not only is the location of each truck known but if someone gets in a tight spot help can be obtained within a few minutes instead of an hour or two. It also saves travel time on equipment.

Plant Housekeeping Techniques

Sludge Hopper Wash-Down

Under the hot Florida sun, raw sludge clinging to the walls of the sludge hopper soon produces odors. To clean the hopper back under a ledge that couldn't be hosed down, a lawn sprinkler of the "Rainbird" type was installed in an inverted position. A full circle of spray washes the corners and the rotating spray arm travels just slowly enough to wash down the walls.

The sprinkler uses fresh water and is turned on manually while the last hopper of sludge is being pumped. It does a beautiful job, not only under the ledge, but on the entire hopper. More automation could be incorporated by use of a solenoid valve in the sprinkler supply line controlled by the sludge pump motor control.

Clarifier Scum Trough Spray

Various methods have been tried to keep the scum trough and scraper arms clean. Usually when the operators pump scum the clarifier scum-scraper arm is on the opposite side of the tank, or they forget to hose it down when there is opportunity. Also trouble was experienced with the wiper blades not wiping clean. The use of a board instead of a heavy neoprene wiper was unsatisfactory. Finally a 3-in. wide nylon brush was fastened on a board, ½-in. thick. This made an excellent wiper blade. A double spray arm (Fig. 1) was installed over the scum trough with the sprays directed straight into the trough and also angled in from the back side of the trough. The sprays are actuated by the scum arm raising a long angle iron which operates a hydraulic control valve. The length of the angle iron governs the length of time the spray will stay on. The spray arms were fabricated from ¾-in. galvanized iron pipe with drilled holes. Water supply is from the plant system.

During six months of operation the system has given satisfactory results. It not only keeps the scum arm and

*Reprinted from Sew & Ind. Wastes, Vol. 28, No. 5, p. 691 (1956)

FIG. 1.—PRIMARY clarifier scum trough spray cleaning apparatus. Note control arm operating hydraulic valve.

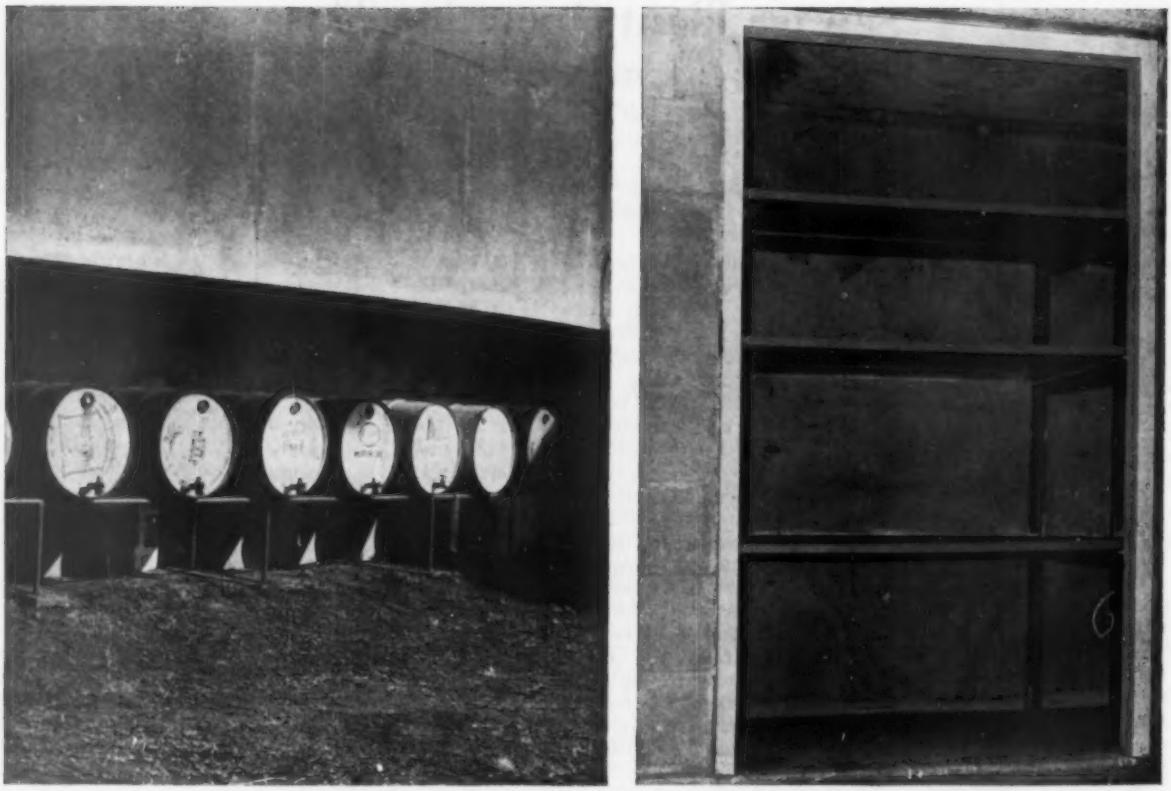


FIG. 2.—SPACE under clarifier overhang is utilized for storage.

trough clean, but also keeps the tank surface relatively free from floating solids.

Effluent Utilization

At present the treatment plant effluent is utilized only in the heat exchanger which cools the water jacket water of a dual-fuel diesel engine generator. Sufficient extra power is available to operate a large-size irrigation pump. Tentative planning for the future includes the use of plant effluent for irrigation, chlorinator ejector water, equipment wash down and foam control. A fine spray on foam appears to be an effective control measure.

Filter Fly Control

One important, but often overlooked method of odor control is the regular and frequent washing down of scum pits, clarifier walls, flumes, weirs and other structures that come in contact with the sewage. Keeping the spray nozzles on the distributor open is important in order to prevent septicity in any part of the filter. On many distributor arms, a part of the sewage runs back under the nozzle on the outside of the arm and a slime growth may form. If this is not cleaned periodically, filter flies will breed there.

Heavy growths of moss on the trickling filters at the Orlando plant were difficult to control. The plant hydraulics would not permit control of the moss and filter flies by flooding the secondary filters. Putting the filter out of service and drying out the moss was not feasible due to attendant odors.

As a solution, the feeding of chlorine into the filter influent was attempted. The chlorine was fed directly from a one-ton cylinder through a pressure reducing valve and a ¾-in. plastic water hose. A stone diffuser was used on the end of the hose. The chlorine residual at the end of the filter arms was checked and the dosage controlled at just under 10 p.p.m. By the time the ton of chlorine was emptied the filter stone was cleansed of moss. There were no problems due to clogging, nor was the clarifier overloaded. Filter flies and odors were completely eliminated.

Storage Space

Some clarifiers are constructed above grade so that the weirs and overflow channels overhang the clarifier wall. The space under this overhang may be utilized for storage (Fig. 2) in mild climates. Under one of these overhangs a concrete floor was poured and the space blocked in. Shelves were installed, making a good fireproof place for storing paints and lubricating oils. These locations were also used to advantage for a pipe rack and drum storage.

Float Controls

Plastic coated stainless steel fishing line has proven very satisfactory for use on lift station float controls. Stainless steel tapes had to be replaced every three or four months. Since the fishing line has been used there have been no replacements. The line costs less than $0.02 per foot and tests for 60 lb.

Liquid Sludge Loader

Liquid digested sludge has found increased acceptance among nursery men, park department personnel and local farmers. To accommodate this demand, facilities (Figure 3) were recently installed to deliver the sludge directly into tank trucks. The arrangement of the sludge beds and driveway at the Orlando plant makes the illustrated installation both effective and economical. An arrangement similar to this is essential to avoid an

otherwise messy and odoriferous condition.

Odor Problems

Odor problems occur at the Orlando treatment plant the same as they occur at any plant. Relatively few sewage treatment plants have been without an odor problem at one time or another. Sewage always will have an odor but operating personnel would like to feel that they are doing a much better job today than they were doing some years ago. Nevertheless there apparently are more and more complaints about sewage odor. As one man so aptly put it, you can clean and beautify all you want and use all the psychology possible, and these things may help for a while, but if Mrs. Jones smells sewage long enough she will ultimately complain. Thereafter anything done will do very little good until the odor is gone; even then she will still complain at the slightest provocation. The public didn't complain too much about odors in former days and yet, with modern treatment facilities and improved methods, the plant superintendents are being flooded with complaints. There are a number of possible reasons for all the fuss.

1. The public is being awakened by manufacturers of odor control material to the fact that there is no need to smell sewage odor or any other obnoxious odor. Advertising by manufacturers of odor control materials and statements that sewage treatment plants, if operated properly, will be 100 per cent odor free, have resulted in the construction of residences right up to the treatment plant fence line. Usually the residents do not get any odor for a week, a month, or maybe longer; then a filter is flooded or an unusual amount of supernatant is withdrawn, or the sewer line crew opens a sewer that has been plugged a week or two, and everyone complains.

2. Some consulting engineers have been convincing the municipal officials and the citizens that modern sewage treatment plants don't smell and practically operate themselves. As a consequence cities build their treatment plants not far enough away from inhabitable areas and developers build too close to existing plants.

3. The increased use of garbage disposal units in the home has had a great deal to do with the increase in the grease and organic load at both the treatment plant and lift stations. The odor of rancid grease is nauseating even to the plant operators. The use of these grinders means the sewage treatment plant will receive not only the domestic sewage but also the garbage. Sewers that formerly operated satisfactorily with ordinary domestic sewage become coated with grease, and the increased solids loading causes the sewage to turn septic before reaching the treatment plant.

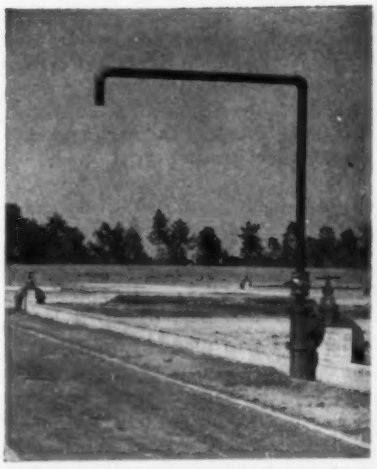


FIG. 3.—LIQUID sludge loader for tank trucks.

4. The growth in population and industry has resulted in increased pollution to the extent that the public is recognizing the fact that something needs to be done.

Odor Control

In an effort to reduce odor complaints, special attention has been directed to conditions at the numerous sewage lift stations. The relatively flat topography of Orlando makes the use of these pumping stations mandatory. Stations range in size from small installations in the residential areas to large facilities in heavily built-up sections. Each station receives a daily checking from the lift station maintenance crew.

The following have helped to ease the maintenance task and reduce odors:

1. Chlorination facilities are utilized at some of the large lift stations to control the septicity of the sewage.

2. All wet well vents in some stations are sealed and ventilation is provided through flagpole vents.

3. Sewer gases are trapped and vented back through the house vents and manholes.

4. On odor counteractant is either dripped or sprayed into the lift station wet well.

Flagpole Vents

The 40-ft. flagpole vents are constructed by the treatment plant staff from a length each of 6-in. and 5-in. diameter steel pipe. The poles are fabricated by welding and set on a ¾-in. base plate which is bolted to a concrete base. A pipe connection is provided from the vent stack to the wet well. Each pole is complete with a lanyard, although flags are not usually flown.

To utilize the vent stacks all openings in the lift station are sealed, except the influent lines and the vent stack line. When the wet well is filling the sewer gases are forced up and out the stack. The 40-ft. height is sufficient to obtain good dispersion of the gases. When the well is pumped down, fresh air is drawn in through the vent. In other words the wet well "breathes" through the flagpole vent stack.

When blowers are used to increase the ventilation they are set to blow into the wet well, thus causing the stack to discharge only. The use of a chemical odor counteractant in the vent stack is very effective.

Wet Well Gas Trap

As the sewage flows into the lift station it draws gases into the wet well from the sewer lines, provided the influent line is not flowing full. If the lines would flow full or if the inlet could be blocked off to prevent the entrance of gases, then the odors at the wet well would be reduced.

To accomplish this closure a tee, with the run in a vertical position, was installed on the influent pipe. In the inlet shear gate slot a low gate or baffle board was installed so that sewage would back up sufficiently to cover the bottom of the tee. A plug was sealed into the top of the tee in such a manner that it would be easy to remove for cleaning and inspection.

The trap works fine, with a minimum of maintenance. Odors at the station are reduced and the sewer lines are vented through the manholes and house vents instead of coming into the station.

Odor Counteractant

As an additional method of odor control, a liquid odor counteractant* was used in the wet wells of the lift stations. This counteractant has been the most successful material used to date. Apparently it creates a film over the surface of the sewage, counteracting the hydrogen sulfide as it is released from the sewage.

Both spray and drip systems of application are used at the large lift stations while a drip system only is

*"Refreshnaire," a proprietary compound distributed by Refreshnaire Treatment, 3256 E. 11th Ave., Hialeah, Fla.

used at the small stations. Sight-feed oilers are used in the drip system so the amount applied can be closely regulated. The feed rate at the large lift stations is 75 lb. per day, a decrease from a maximum of 125 lb. per day.

The odor counteractant is also used at the treatment plant. It is dripped into the influent raw sewage and also fed just prior to discharge on the rotating trickling filters. Dosage rate is approximately 0.5 p.p.m. Odors have been kept under control except for a couple of times, once when some supernatant was drawn to a sludge bed and again when a flooded filter was drained. In the rush to control the odors, too much counteractant was used and the resulting complaints were caused by the predominant counteractant odor.

Odor Complaints

Most complaints about odors from the treatment plant occur in the evening or early morning. The complaints are most prevalent a couple of hours before and after sunset. Usually the workday activities of the neighboring residents taper off about this time and they relax. As a result, they are more aware of any strange odors. Atmospheric conditions at this time of day probably play a part in the prevalence of odors. On days with only a slight breeze and high humidity the complaints may persist on and off all day.

Fortunately, most of the odor complaints are not chronic, and are usually received all at one time. The nearest homes are approximately 300 yards away and many times the neighbors get odors before they are noticed at the plant. Therefore, by close cooperation between the neighbors and the plant personnel, corrective action is quickly taken when odor complaints are received. After the call is received, the person calling is invited to call back if the odors do not subside. Visits are also invited. Usually, the source of the odor can be found and counteracted in a short time. Complaints at the lift stations are now rare.

The combination control using prechlorination to keep the sewage as fresh as possible and treatment with the odor counteractant to combat hydrogen sulfide at both the treatment plant and lift stations has been fairly successful.

It would be a boon to sewage treatment plant personnel if research studies could be undertaken to evaluate the effectiveness of the many odor-control chemicals now available. Actual plant-scale evaluation should be carried out. Most treatment facilities do not have the time, personnel or equipment to properly evaluate the full effectiveness of these products.

General Appearance

Although flowers, shrubbery, clean windows and polished floors may not help the odor, it is an essential part of good public relations. It is difficult for citizens to complain heatedly about odors if the treatment plant is kept spotless.

Visitors to the Orlando treatment plant during the winter are always impressed by the ducks swimming in the secondary clarifiers (Figure 4). The ducks arrive each winter just after Christmas and stay until March. They fly between a small lake near the plant and the clarifier where they feed on filter fly larvae. Most visitors remember this feature of the plant and indirectly praise the operating personnel for the excellent job of sewage treatment.

FIG. 4.—WINTER visitors (ducks) feeding on filter fly larvae in the secondary clarifier.

Industrial Waste Ordinances

General principles, responsibilities and methods of application

by DEAN M. TAYLOR

Senior Sanitary Engineer, Engineering Division, Department of Public Works, Cincinnati, Ohio.

THE SOUNDNESS of an ordinance is tested by its application. Original mistakes crop up to plague those applying it. What seems perfectly clear at first may turn out to be a point of controversy later on. Experience often reveals omissions and indicates necessary corrections. The advantages of short form over long form ordinances are thus brought out. With a short form the person or persons administering the industrial waste ordinance can change the rules and regulations when necessary[1]. For example, the Industrial Waste Ordinance of the City of Cincinnati, Ohio, has been amended twice since adoption in 1953.

It takes time to put an industrial waste ordinance into operation. If representatives of industry have participated in discussions of the program from the beginning they are better able to participate in the final program since they can anticipate their responsibilities and take steps to meet them. Much preliminary information is needed to initiate the program and all participants should be primed to establish policy and procedures for reasonable deadlines. Experience has shown the desirability of establishing dates for compliance. Some industries always wait for municipal government to take the initiative. Of course they don't like to increase their overhead but industrial waste disposal is a community problem which must be solved by democratic community effort.

Types of Ordinances

Industrial waste ordinances may be placed in two general categories: (1) those controlling discharge of wastes to sewers; and (2) those providing service charges in addition to control of discharge to sewers. Probably all existing industrial waste ordinances contain rules and regulations defining the conditions of acceptance or refusal of certain wastes but few ordinances provide for special service charges for industrial wastes, above and beyond the usual volume charges.

There are many phases to a program of special service charges. As a whole it is complex and the history of its development is relatively short. So many plans have been proposed that public officials, inexperienced in such matters, have been confused. When they come to the question of special charges for industrial wastes, they throw up their hands and say they don't know how it can be done. This is the time to seek advice and work out the problem in a practical manner. Each community should study its own needs and develop an ordinance to meet them.

Responsibility For Application

It may be said that the municipal government or regulatory agency is responsible for applying an industrial waste ordinance but actually this responsibility is a matter of enforcement. If industry assumes a positive attitude and moves to meet the requirements of an ordinance, then the government agency will not have to take police action. When all parties can meet with mutual understanding and respect, application runs smoothly and goals are reached.

When an industrial waste surcharge is to be applied, the enforcing agency will probably move quickly to collect fees. Speed will also be exercised if prohibited wastes are seriously affecting public property, operations, safety, health, or welfare. Industries will also be very much concerned with surcharges, particularly when they receive their first bills for same. If industrial management is alert it will initiate study of its industrial waste problems as soon as the ordinance is passed. It will also familiarize itself with all the requirements of the ordinance so that it can meet them on schedule. Enforcing agencies should initiate such programs with patience but there is a limit to procrastination and downright lack of cooperation. Moreover, ignorance of the law is no excuse for nonconformance.

Some industries have serious industrial waste problems, others do not, Industrial waste disposal is an operation to be reduced to the lowest possible cost like any other operation in an industry. Smaller industries may prefer to let governmental agencies take all the initiative because they think it will be cheaper. This may be false economy because the enforcing agency is responsible for applying the rules and regulations, not working out the industry's problems. Employees of the agency can make certain suggestions, but professional ethics place certain limits on professional services.

Application by Industry

An industrial waste ordinance can present many problems to an industry. It can also solve certain problems for the same industry. Therefore, it is important that each industry study its own situation and evaluate it. This is particularly true when there are sewer service charges for wastes in addition to certain prohibitions for them.

Some industries have serious waste disposal problems; others have relatively simple ones. Ordinarily, the size of the company determines the quantities of wastes rather than the qualities. When management understands the objectives and directives of an industrial waste ordinance, it can take realistic steps to meet its requirements. If competent people are

Ed. Note: In an article in *Water & Sewage Works* (*April* 1956, *p.* 173), Mr. Taylor discussed the policy, legal, financing, engineering and technical requirements inherent in establishing ordinances for the control of industrial waste discharge into municipal sewers.

made responsible for a waste disposal program and are backed by management, then reasonable progress should be made. If a company does not have technical personnel who can carry out an effective industrial waste program, then thought should be given to employing a competent consultant, for which industry should pay fees comparable to services rendered. The consultant's services should be commensurate with needs.

Industrial Waste Survey

Knowing your own problem is axiomatic. Some companies know much about their wastes, others do not. After summarizing the known facts, action can be taken to obtain the necessary additional information.

Making an industrial waste survey is a must. It reveals both characteristics and source of the wastes and shows or indicates proper methods for elimination or disposal. Articles describing industrial waste surveys and valuable sources of information[2-6] and several good textbooks describe industrial processes and equipment, wastes produced, and practical methods for wastes disposal[7-11].

Persons making an industrial waste survey have flow diagrams for all manufacturing processes as well as sewer lines in order to select proper gaging and sampling points. Gaging can be a difficult problem, praticularly in old plants with many hidden sewers. It may be worthwhile to relocate sewers and build new gaging stations to obtain data on a permanent basis. It is necessary to study the requirements of the Industrial Waste Ordinance to determine what waste constituents should be selected for analysis. In addition, the manufacturing processes should be studied for selection of other constituents of importance. Industrial wastes present many problems in analytical chemistry. Care should be taken in selecting methods acceptable to the regulatory agencies and consistent with good practice. If the samples are sent out to commercial laboratories, analytical methods should be stipulated.

Making the survey involves many technical details. Failure to consider seemingly unimportant details may invalidate much data. Production and operational schedules should be studied to determine proper survey times. It may be desirable to obtain information for abnormal as well as normal conditions. The length of the survey is important, for representative values and should extend over full operational cycles (at least 1 week). Both grab and composite samples have value if properly interpreted. It has been customary to collect 24-hr. samples composited in proportion to flow. Accurate hydraulic measurements yield necessary, valuable information. The sampling interval should never exceed 1 hr and more properly should be of the order of 10-15 min. In general, the shorter the time interval the more truly representative will be the sample.

Sampling techniques and equipment are also important in obtaining representative samples. Manual sampling is practical for limited work, but automatic sampling is more useful for extensive work. Comparable data may be needed to substantiate specific automatic sampling situations.

Handling of samples may be very important, depending upon the nature of the wastes and the analytical determinations to be made. Samples for such analyses as BOD, phenols, and cyanides must be preserved properly. Finally, the laboratory work should be done in the prescribed manner under proper conditions, by trained technicians.

Unfortunately, many industries may obtain erroneous data from their original waste surveys. In Cincinnati this was found to be largely due to improper methods of gaging, sampling, and laboratory analysis. Incompetent or inexperienced personnel cannot be expected to obtain representative data. Some of the more common errors are: improper selection, installation, maintenance, and reading of flow measuring devices; taking only one or a limited number of grab samples; failure to composite samples according to flow rate; sampling only one of several points of discharge to sewers; failure to sample over representative time periods; improper selection of sampling points; failure to sample at short enough time periods; improper sampling techniques; and improper laboratory methods and techniques.

In Cincinnati, engineers of the Sewage Disposal Section examined all waste survey data furnished by industries. Whenever differences between City and company data appeared, Sewage Disposal Section Engineers reviewed all technical procedures with representatives of the companies. It has been possible to establish standards of procedure consistent with the best principles of engineering and laboratory practice.

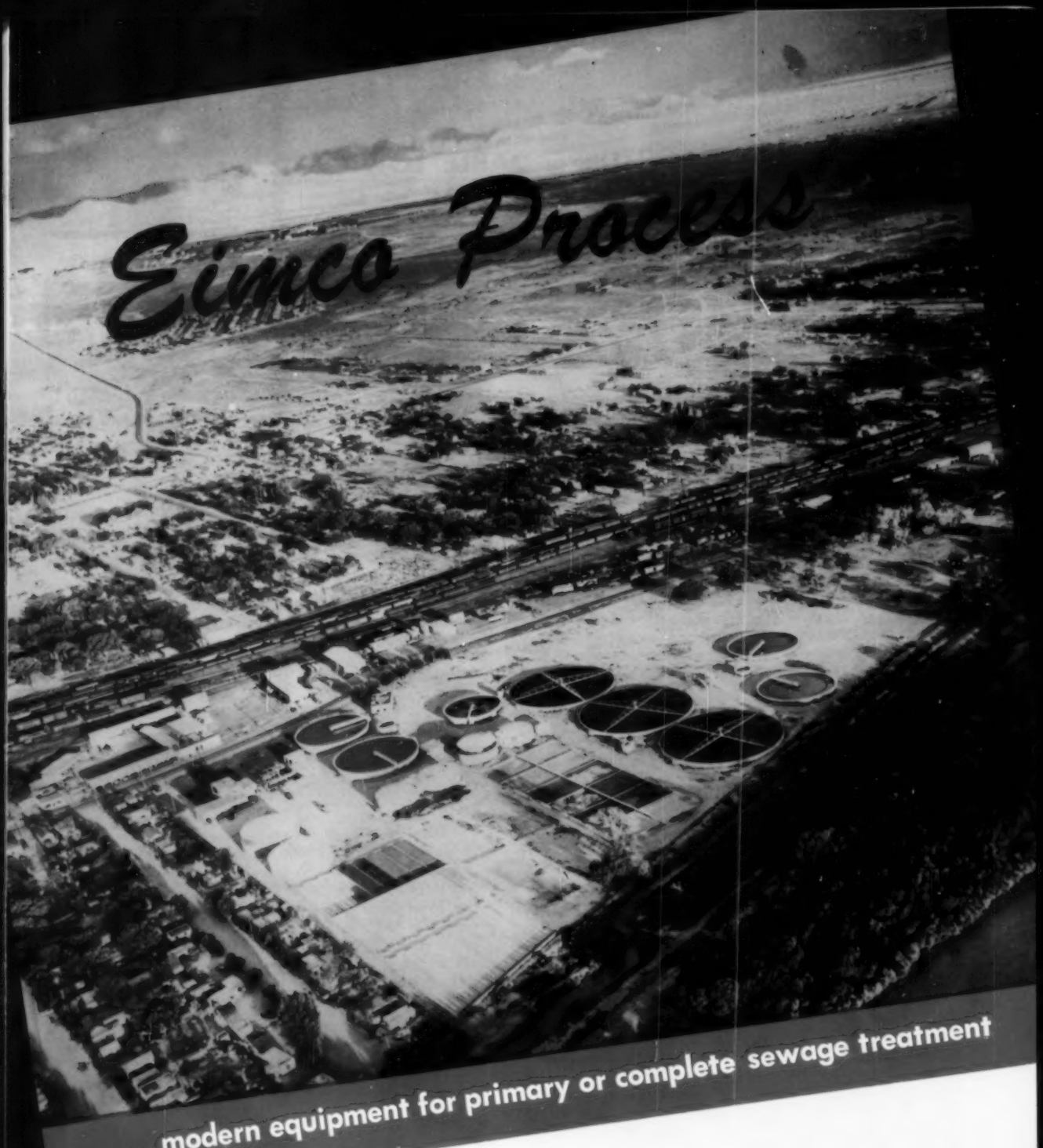
Conformance With Ordinance

After the waste survey has been made, industry should determine its status with respect to the industrial waste ordinance. If the survey indicates changes for greater efficiency, it is reasonable to say that management will make them. But if it shows nonconformance with the ordinance, then it may be necessary to make many important decisions.

If it can meet certain requirements, industry has the choice of discharging its water-carried wastes to public sewers or directly to waters of the state. The choice is usually a matter of economics, but it may involve political considerations or public relations. Sometimes it is feasible to segregate wastes and discharge unpolluted water to waters of the state and polluted water to public sewers. When a service charge is levied for volumes of water discharged to sewers, it is practical to discharge as much water as possible to waters of the state. On the other hand, it may be cheaper to discharge all wastes to public sewers than to segregate sewers or pretreat the wastes. If an industry has been discharging wastes to the public sewers before the industrial waste ordinance was passed and has no access to waters of the state, then it has no choice but to meet the requirements of the ordinance.

Meeting the prohibition requirements of an industrial waste ordinance usually is a matter of reducing waste constituent concentrations. There are a number of methods available: reuse of water and materials; storage and equalization of waste flows; good housekeeping; process and equipment changes; proper mixing of wastes; recovery units; and waste treatment. The last method may be applied at the source, at the point of plant discharge, or any place between.

Numerous methods are employed for financing sewage disposal systems. When general taxation funds are used, industries only have to worry about concentrations of certain restricted waste constituents, if there are any such restrictions. When there are only volume service charges, industries can reduce water usage to a minimum and forget about concentrations provided there are no special prohibitions. When there are service charges for both volumes and concentrations of certain constituents (usually suspended solids, BOD, and chlorine-demand), then industries have real problems trying to balance the one against the other so as to reduce the total cost. All of the previously mentioned waste-reducing methods can be used and when data from a waste survey are available, it is possible to arrive at a practical minimum cost.



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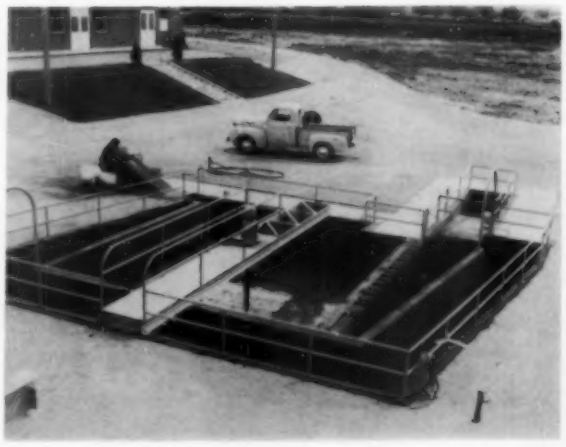
GRIT SEPARATORS

EIMCO-PROCESS GRIT SEPARATORS are available in tank sizes up to 40' square. Continuous mechanical grit removal and thorough grit washing are accomplished in one compact unit. The square collection tank is equipped with a heavy-duty rake mechanism which moves the sand and heavy organic material outward to the washing compartment. Adjustable deflectors at the inlet distribute the flow and prevent short circuiting.

The grit washer is a spiral classifier installed in a trough attached to the collection compartment. The spiral has a double pitch from the bottom to the water level and a single pitch to the upper end with special wash sprays. This design combines quick removal of the grit from the collection chamber with thorough washing for removal of the undesirable putrescible organics, thereby delivering a clean, well-dewatered grit. The screw or spiral type washer minimizes the required area and contrete, giving corresponding installation savings.

For collectors over 30' square or installations where the grit must be elevated greater distances, the double screw, Type DSB, grit separators are recommended. The twin deck washing compartment provides excellent control of the washing action and may be advisable on smaller units if excessive organic loads or other special conditions are present.

The Type RB, or rake-type washer, also is available in all standard sizes. For separate grit washing where it may be necessary to pump the unwashed grit from a grit collection chamber far below the ground surface, the Type GSW grit washer is used. The unit is a tangentially fed conical separation chamber with a dual pitch enclosed spiral washer. The unit delivers a well-washed and dewatered grit and can be located at any desirable remote area from the collector.



CLARIFIERS

EIMCO-PROCESS CLARIFIERS are available in four basic types in tank sizes up to 325' diameter. All machines are equipped with a heavy-duty drive unit in a cast iron housing with the gearing mechanisms running in oil. The clarifiers feature a comletely balanced design—with all components of equal torque carrying capacity to insure proper, dependable operation.

For tanks up to 45' in diameter, the Type B, or beam supported mechanisms are recommended. Either a center or side inlet can be used depending upon the specific conditions.

For tanks up to 200' diameter, the Type C, or the center column supported mechanisms are recommended. The trussed arms are driven by the center-mounted drivehead through a center cage. If desired, the units can be used in square basins with pivoted extensions added to the ends of the two arms. The pivot arms sweep the settled solids from the rounded corners.

Type T, or traction type units, can be used for tank diameters up to 325'. The mechanism is driven through a truss and center assembly by a traction wheel on the tank wall. This type of mechanism is considerably lower in installation cost for the exceptionally large sizes

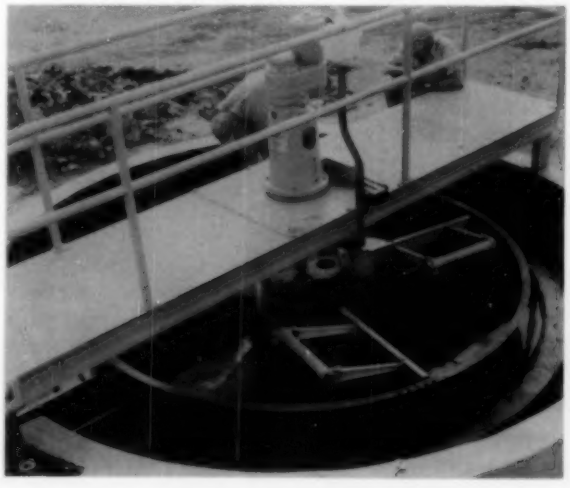
Special features such as the spiral inlet diffuser and large diameter feedwells are available on all machines. These improvements, pioneered by EIMCO-PROCESS ENGINEERS, provide better solids removals and more flexible operation at little or no additional cost.

FLOTATOR-THICKENERS

EIMCO-PROCESS FLOTATOR-THICKENERS are available in all tank sizes up to 24' diameter, for the thickening of sewage sludges. The problems associated with the concentration of many secondary sludges, i. e. activated sludge or sludge from a tricking filter plant, are well known. In gravity type thickeners the solids often tend to bulk or float and rarely settle to the proper concentrations. The FLOTATOR-THICKENER takes advantage of these characteristics and through proper design of the entire system achieves dependable concentration to a fraction of the original volume without difficulty.

The thin sludge influent is pressurized and then released inside the tank through a special diffuser system. The air comes out of solution in fine bubbles carrying the suspended solids into the concentrating portion at the surface of the tank. Here the concentrated sludge is skimmed for disposal or further processing. All EIMCO-PROCESS FLOTATOR-THICKENERS also are equipped with sludge raking arms at the tank bottom. Any heavier solids which may not float are concentrated by the rakes and moved to the center for conventional withdrawal.

The extensive laboratory facilities for testing, operating experience and design know-how place the EIMCO-PROCESS FLOTATOR-THICKENER alone in the field. Proper application and service of these well designed machines have given them a reputation for outstanding operation. The economics associated with removals of large quantities of water from these sludges prior to digestion or subsequent vacuum filtration have been published extensively. The small investment for these high-capacity, inexpensive units easily is justifiable in almost all plants.



EIMCO ROTOBELT

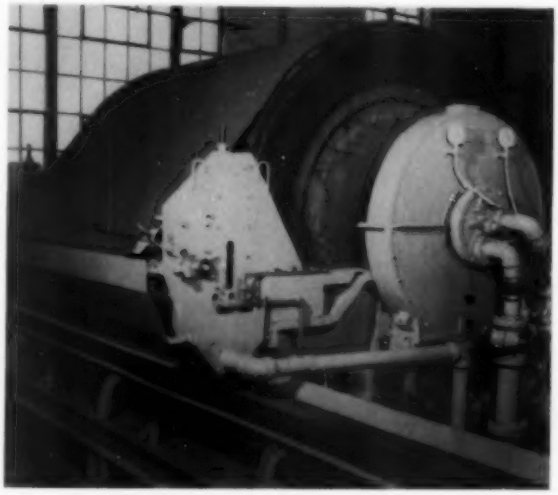
The Eimco Rotobelt—available in a full range of sizes from 18" diameter x 1' face to 14' diameter x 14' face—is a vacuum drum filter especially designed to maintain a clean filter medium and provide dependable operation at high filtration rates. Through continuous removal of the belt medium from the drum, proper cake discharge and a clean filtering surface are assured.

The Eimco Rotobelt normally is equipped with a variable speed drive for operation between one and six minutes per revolution.Positive seals at both edges of the belt, at the ends of drum deck periphery and between adjacent drum sections provide a sharp separation between pick-up and dry zones and provide operation at high vacuums with the standard size vacuum equipment and horsepower requirements.

The Eimco Rotobelt is equipped with a stainless steel woven wire belt medium that carries the filter cake off the drum to a small diameter discharge roller where the cake separates sharply from the medium without scraper contact. The medium then passes into a wash tank with separate drainage facilities. Sprays are available for periodic or continuous cleaning if necessary, before the medium returns to the drum.

This metal medium gives essentially the same solids retention and filtrate clarity as is obtained from cloth covered units.

The Eimco Rotobelt can be equipped with Eimco



"Hy-Flow" design, a streamlined passage system that conducts filtrate and air through the filter and valve at a minimum of hydraulic resistance.

Existing Eimco drum filters can be converted to Rotobelt operation. In sizes up to 6' diameter x 6' face, the Rotobelt can be furnished as a package filter station complete on one platform.

NON-CLOG DIFFUSERS

EIMCO-PROCESS NON-CLOG DIFFUSERS have been specially designed to meet all types of sewage plant aeration requirements. Whether they are used for pre-aeration of the raw sewage, in EIMCO-PROCESS OXIDATORS, in the aeration tanks of activated sludge plants or in other special applications, the same trouble-free operation and excellent air distribution are obtained.

The diffuser consists of a special cone with a flat annular top surface. A weighted cover guided by three adjustable and non-corrodable cap screws rests on the top of the cone. When the air pressure reaches the proper design level, the cap raises slightly and the desired fine air bubbles pass through the annular opening. Only when the pressure is attained is there an opening; therefore, no clogging of the diffuser occurs. An air failure or any other plant difficulties merely cause the cap to quickly close the annular opening, thereby preventing the difficulties usually encountered in other types of diffusers. The cone is easily installed and adjusted in the field with the cap weight determined previously to meet the particular plant design conditions.

DIGESTER MIXERS

EIMCO-PROCESS DIGESTER MIXERS are available in two types, the Type BM for small, single-stage digesters and the Type RDT for all types of service. The Type BM mixers keep the digester contents thoroughly mixed by a rotating vertical shaft to which lower sludge rakes and upper scum breakers are attached. The rugged motor-reducer drivehead is equipped with a torque indicator and cutout to protect the unit from overloading and provide a convenient means of operational control.

The RDT mixers are available in sizes of from 3 to 15 HP providing recirculation capacity up to 15,000 gpm. The special non-clog propeller is inclosed in a removable draft tube with an integral steel gas dome. The dome bolted directly to the digester cover contains all of the necessary structural members, with no additional lateral or bottom supports required. This rigid, unitized design permits the removal of either the entire assembly or the mixing mechanism, without draining the digester, and prevents any interference between the rotating and fixed components due to a possible misalignment. The heavy-duty bearings spaced at an adequate distance easily take the heavy thrust loads often created by the recirculation of a large amount of heavy scum. These features have given the large number of RDT mixers an outstanding service record.

The mixer drive unit is reversible, creating either an upward or downward flow. A stationary deflector mounted slightly above the water level gives the desired streamlined flow pattern during upward recirculation. A special mixer design often is furnished wherein the unit serves both as a mixer and heater. The draft tube is jacketed and proper pipe connections provided through the mounting plate for the heating medium. "Because of sludge turbulence, the heating surfaces remain clean and insure excellent heat transfer."

ROTARY DISTRIBUTORS

EIMCO-PROCESS ROTARY DISTRIBUTORS are available for all bed sizes up to 200' in diameter. Several types are recommended, depending upon the desired flow ratios and the available head.

Every provision has been made to insure reliable, trouble-free operation. Leather seals designed for long service and easy replacement are a standard feature. The open center well design provides easy access for inspection or seal replacement when that becomes necessary.

For simplicity of installation, all arm assemblies are furnished in sectional fabrication. Pipe arms normally are used for smaller flows, fabricated steel rectangular arms for large flows. All distribution orifices are straight-edged without sharp corners to provide the proper, even flow distribution.

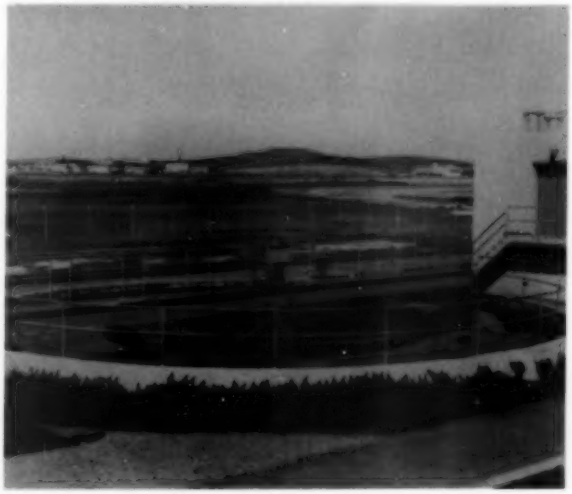
With the unique compartmented arm design, widely varying flows are handled with a minimum head loss. For less demanding operating conditions, the simple and most economical center assembly without internal weirs is furnished. On all units, a large diameter precision bearing is used to insure proper stability and extended service without attention.

OXIDATORS

EIMCO-PROCESS OXIDATORS combine aeration, flocculation and sedimentation in a single circular tank. The aeration and internal sludge recirculation keep the sewage fresh, give increased BOD removal, increase floccule size and minimize scum formation. Coupled with conventional and upflow sedimentation, the exclusive OXIDATOR action gives increased suspended solids removals.

The influent to the OXIDATOR enters through the center column, passes into the center compartment for aeration and recirculation with previously formed floc, and then flows into the outer annular compartment for upflow sedimentation. Discharge of the settled solids at the maximum concentration is obtained by either of the two special EIMCO-PROCESS features—through the center sludge outlet protected by a special deflector-baffle or through an annular sludge trough outside the aeration well. Both designs provide the desired "protection" of the concentrated sludge from disturbance by the agitation in the center well.

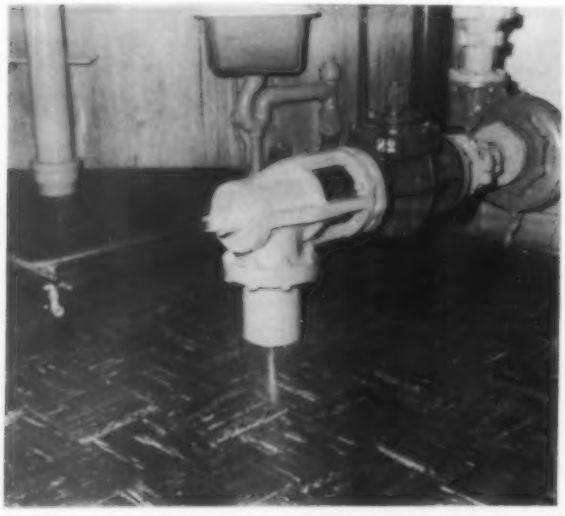
Long or short aeration periods, gentle or intense aeration—agitation and adjustable sludge recirculation rates make the OXIDATOR the most flexible of all sedimentation equipment. Because of the higher solids and BOD removals at minimum additional initial and operating costs, the OXIDATOR can provide an intermediate treatment if used alone or substantially reduce total plant investment if used with secondary treatment.



The air can be applied in several ways, by (a) an air lift in the center column, (b) porous tubes, (c) EIMCO-PROCESS AERATION NOZZLES, (d) perforated manifold near the surface or (e) dissolved air in the pressurized influent. Through proper construction, any of these methods alone can, or in combinations will, provide the proper aeration, flocculation and sludge recirculation.

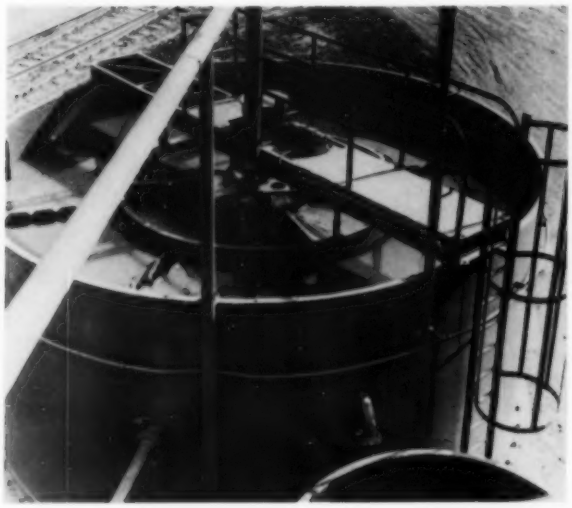
CLEANABLE SIGHT GLASSES

THE EIMCO-PROCESS CLEANABLE SIGHT GLASS is a unique device providing reliable visual observation of sludges or liquor flowing inside a pipe. With the standard flanged fittings, the inexpensive CLEANABLE SIGHT GLASSES can be installed in any L section of 4" or 6" standard pipe just as any other fitting.



The pyrex glass section is mounted with neoprene gaskets in a water-tight ribbed casting so that the glass carries no loads or strains. The special internal wiper can be used with or without the solvent, which is injected through the hollow brass wiper rod. With this cleaning or wiping provision, a clean inside surface and clean view of the material flowing is maintained. This allows visual control of sludge withdrawal, supernatant withdrawal or any other plant stream. A large number of these devices have been sold with an enthusiastic response from all plant operators.

FLOTATOR-CLARIFIERS



Combining flotation and sedimentation in one circular tank, the EIMCO-PROCESS FLOTATOR-CLARIFIER separates floating, floatable, rapid and slow settling solids from the sewage liquor at a high overflow rate. The FLOTATOR is located in the large diameter feedwell of the clarifier with the surrounding annular zone for sedimentation.

A portion of the effluent is pressurized and added to the influent which enters the flotation compartment through the center column. As the pressure is released, the minute air bubbles, which form as the air comes out of solution, carry the suspended solids to the surface. The scum blanket is skimmed and combined with the underflow sludge, which is moved to the center discharge point with conventional raking arms. The clarified effluent flows over the peripheral launders in the outer annular sedimentation compartment for disposal or further treatment.

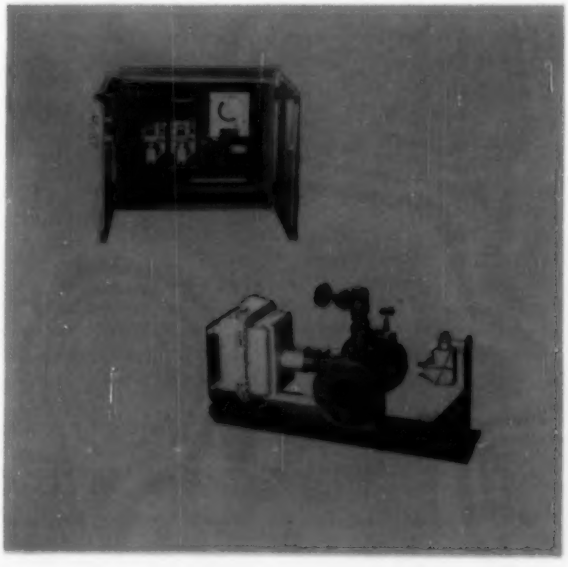
Using about 50% less area, EIMCO-PROCESS FLOTATOR-CLARIFIERS are giving equal or greater removals of suspended solids and BOD than conventional primary clarifiers. In addition, the rapid suspended solids removals plus low overall retention time give excellent odor-free operation with near septic sewage under greatly varying flow conditions. The savings in initial investment and the inherent flexibility in operation make the FLOTATOR-CLARIFIER an ideal primary treatment unit.

FLOTATOR-CLARIFIERS are available as Type B, or beam supported machines, for tanks up to 45' diameter and in Type C, or center column supported machines, for tanks up to 100' in diameter. The operation of all units is essentially the same, with the method of support determined by economic and structural considerations.

ELECTRONIC SLUDGE THICKNESS CONTROLLERS

THE EIMCO-PROCESS SLUDGE THICKNESS CONTROLLER is the first and only reliable scientific device successfully controlling the density of sewage sludge withdrawn from clarifiers or digesters. Through the unique arrangement of the light source and photo-electric cell, the CONTROLLER is extremely sensitive to variations in sludge thickness. A program timer controls the pumping cycle so that sludge is withdrawn only when at the maximum attainable concentration as predetermined by plant operational tests. The unit is easily adjustable and after initial setting requires little or no attention.

There are many advantages to being able to transfer sludge of the proper density on an automatic 24 hour basis. Full utilization of digester capacity, optimum operation of vacuum filters, lower pumping costs or proper control of secondary sludge density are only a few potential advantages, depending upon the application. Units have been in operation several years without difficulty and the achievements and fine service record of these CONTROLLERS make them an outstanding contribution to modern plant control.



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In addition to the equipment represented in this bulletin Eimco-Process Engineers, Inc. furnishes a complete line of equipment for water, sewage and industrial waste treatment including;

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Bulletin SM - 1009, 50M, 7-9, Printed in U.S.A.

Industrial Waste Treatment

Most published articles and textbooks on industrial waste deal with specific problems and their solution. The information is usually classified according to industries. Industrial waste engineers can obtain valuable information from such literature, but they would do well to study the basic principles of industrial waste treatment processes and equipment. Many treatment problems are similar but not exactly the same.

Laboratory data should be put through the pilot plant stage before full scale applications. Before purchasing equipment, considerable thought should be given to the overall cost, including initial, operational, and maintenance costs. The reliability of the manufacturer is also important. It may be possible to try out a small-scale unit.

Industry in the Metropolitan Sewage Disposal Area of Cincinnati, Ohio, has taken positive measures in waste treatment as evidenced by the expenditure of 6-7 million dollars in the period from 1953 to present. Most of this money was spent during the first year of application of the Industrial Waste Ordinance when a bonus clause permitted the first year's surcharges to be based on waste surveys made at the end of a one year grace period.

Application by Local Govt.

Local policies regulate methods of application. Consequently, there is no specific method for initiating action and applying regulations. Local officials will save time by dealing directly with management of industry and explaining methods of application.

Operational requirements are determined by the size of the community, the extent of industrial development, and the scope of the industrial waste ordinance. Small communities usually have few industries and, conversely, large ones usually have many. Since ordinances apply only to plant effluents, the number of industries is more significant than their size in applying the ordinance. Adequate, competent personnel and operating funds must be made available to initiate application of an industrial waste ordinance, if it is to be effective. Appraisal of the program will show future needs.

Preliminary Steps

An industrial waste ordinance may be applied to any new or existing sewage disposal program. If there is no existing sewage disposal system or treatment plant, more time may be given to the details of application. This is particularly true with prohibited wastes which would inhibit or prevent certain treatment processes. Depending on the size of the community and the extent of industrial development, there is great advantage to preliminary investigations.

Some of the helpful preliminary steps are: (1) study of the literature; (2) review of directories; (3) sending out questionnaires; and (4) making preliminary field surveys. Where a new treatment plant is under construction, the municipality can develop and apply the industrial waste ordinance before operation starts. The interim period gives time to work out the "bugs". Part II of this article will include examples of how these preliminary steps were applied in Cincinnati.

Controlling Discharge to Public Sewers

Much has been written about control of industrial wastes to public sewers. Manual of Practice No. 3, titled "Municipal Sewer Ordinances" by the Federation of Sewage Works Associations, is a valuable guide. Such control has four major objectives: (1) to protect the sewage collection system; (2) to protect operating personnel; (3) to protect the treatment plant; and (4) to meet effluent or stream standards.

There is considerable controversy about permissible limits for certain waste constituents. This is natural because sanitary engineers are still in the process of finding the true effects of these materials on sewage disposal systems but more factual data may be obtained in time.

Protecting the sewer system is essentially the task of preventing discharge of these industrial wastes which will: corrode or erode the sewers and appurtenances; clog the sewer system; cause explosion or fire hazards; or pollute storm sewers. Protection of operating personnel is accomplished by prohibiting discharge to sewers of toxic materials and explosive or flammable materials. Protection of the treatment plant is a matter of preventing damage to structures and equipment, and to their operation and preventing interference with sewage treatment processes. Protecting the treatment plant effluent to meet certain stream standards generally amounts to control of specific soluble constituents entering the plant. Calcium, magnesium, chlorine and fluoride ions will go right through a plant and give problems to downstream water users.

There is an advantage to requiring permits for discharge of industrial wastes to public sewers. Companies would be required to report quantities of wastes discharged. Duly authorized employees of the controlling agency should be permitted to enter such properties as may be necessary for the purpose of inspection, measurement, sampling, and testing wastes. Information can be kept current and control exercised by requiring that plans, specifications, and other pertinent information relating to pretreatment facilities be submitted for the approval of the authorized official or officials. There is also an advantage to requiring periodic operational records for such facilities.

When industries have been classified according to types of production and wastes, it is possible to outline methods of controlling troublesome wastes. Companies can be placed in four general categories: (1) those producing wastes prohibited from sewers; (2) those producing wastes to be limited in concentration before discharge to sewers; (3) those producing wastes to be limited in both volume and concentration before discharge to sewers; (4) those producing wastes to be limited in concentration as they arrive at the sewage treatment plants.

Field surveys are mandatory. They show actual operating conditions and permit on-the-job discussions with company officials. Also, they are the only means of gaging, sampling and testing by governing officials. All decisions, directives, and reports should be confirmed and clearly stated in letters for future record. There is nothing more difficult or frustrating than trying to solve knotty problems at future dates with no written records.

Checking wastes prohibited from sewers is a continuous job. Even though management of industry has the best intentions, chain-of-command can break down and workers carelessly discharge prohibited wastes to sewers. Systematic inspection of sewers will often reveal offenders. Tracing sewage treatment plant problems back to sources of industrial wastes can be difficult. Some detection can be done by visual inspection, but analytical methods are more convincing. Waste source files are valuable guides.

Controlling concentrations and quantities of waste constituents discharged to sewers and arriving at treatment plants involves sampling and gaging procedures. Some ordinances base limitations on grab samples while others require 24-hr composites. Both methods have value, depending on circumstances. Automatically recording instruments and

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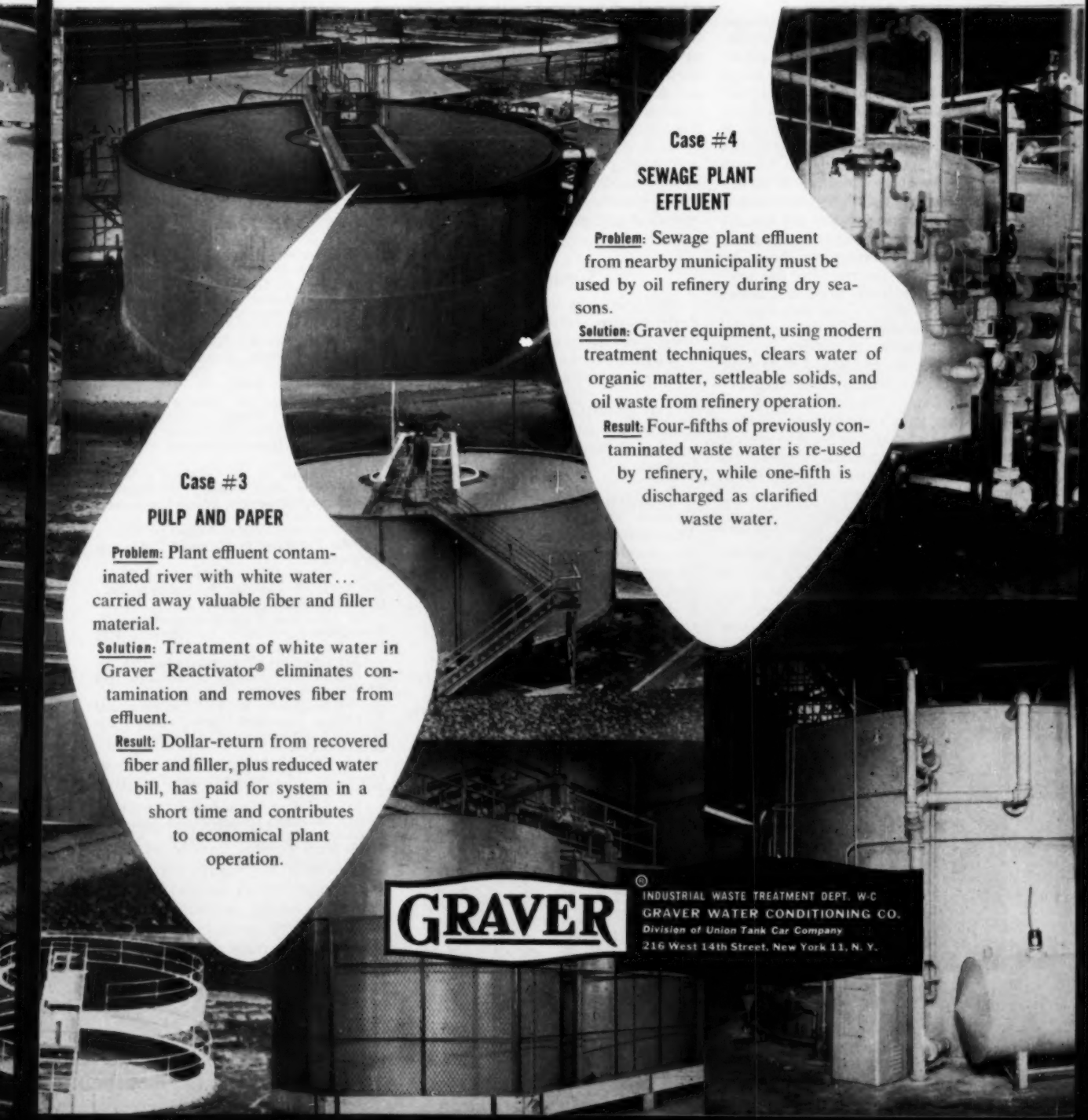
Write for descriptive literature on Graver Industrial Waste Treatment Equipment



Case #4

SEWAGE PLANT EFFLUENT

Problem: Sewage plant effluent from nearby municipality must be used by oil refinery during dry seasons.

Solution: Graver equipment, using modern treatment techniques, clears water of organic matter, settleable solids, and oil waste from refinery operation.

Result: Four-fifths of previously contaminated waste water is re-used by refinery, while one-fifth is discharged as clarified waste water.

Case #3

PULP AND PAPER

Problem: Plant effluent contaminated river with white water... carried away valuable fiber and filler material.

Solution: Treatment of white water in Graver Reactivator® eliminates contamination and removes fiber from effluent.

Result: Dollar-return from recovered fiber and filler, plus reduced water bill, has paid for system in a short time and contributes to economical plant operation.

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samplers are valuable for such work.

Controlling agencies should be prepared to furnish all the necessary equipment and facilities for survey work. One city requires companies to pay for all gaging, sampling, and testing costs[12]. Testing equipment, laboratory facilities and transportation should be commensurate to scope of work. Volumes of work will vary for each program but quality should not be sacrificed for expediency.

Special Service Charges

Because it is impractical to sample and gage wastes from residences, stores, business houses, and public buildings, the usual practice is to establish base values for "normal" sewage and levy surcharges on those wastes exceeding "normal" sewage in terms of certain waste constituents (such as suspended solids, BOD, and chlorine-demand). Volumes of wastes can be measured at their point of discharge to sewers but they are usually determined by water consumption meters. Proper exemptions should be made for water not reaching the sewers (cooling towers, products, boiler blow-downs, etc.). Concentrations of wastes can be estimated from average values for similar industries but the only truly accurate method is to gage and sample the wastes from each specific company. Wastes from certain companies vary considerably, so they have to be checked periodically. Certain industrial associations may base surcharges on units of production, such as barrels of beer, pounds of linens to be laundered, or pounds of skim milk processed.

The task of making industrial waste surveys to establish surcharge rates is similar to that described above for industries. The main difference is that each company surveyed presents new problems for sampling and gaging. All waste line connections to public sewers have to be located and much engineering ingenuity is required to solve gaging problems. Manual sampling for at least five to seven 24-hr days is usually required. When survey programs are initiated, few if any companies will have proper sampling and gaging facilities available for controlling agencies. Some industrial waste ordinances require construction of suitable sampling and gaging stations within certain time periods after passage. Others provide appointed authorities with powers to require construction of same. This latter method allows greater flexibility of application and gives more time to companies with serious problems.

It is important to establish certain operational criteria. Sewage surcharges will be scrutinized by companies subject to them, and it will be necessary to always be on firm ground. Consistent policy will be necessary to maintain equity and good public relations. Standard Methods for the Examination of Water, Sewage, and Industrial Wastes[13] has been universally accepted as a standard for laboratory work. The inadequacies of this book can be met with the use of acceptable, additional procedures. All details, such as sampling and gaging procedures, compositing of samples, and methods of computing average values should be clearly established and explained to those concerned.

Summary

1. Much work is required to apply industrial waste ordinances, particularly when there are sewer service charges in addition to regulations controlling discharge to sewers.

2. The governmental agency is responsible for enforcement but industry should share the responsibility of application.

3. Industry will benefit from a progressive industrial waste program. After making thorough waste surveys it is possible to compare existing conditions with the requirements of the industrial waste ordinance. Cost studies can be significant where there are sewer service charges or surcharges.

4. Helpful preliminary steps in applying an ordinance are:
   (1) study of the literature and reports
   (2) review of directories
   (3) sending out questionnaires
   (4) preliminary field surveys.

5. Discharge of industrial wastes to public sewers is controlled to:
   (1) protect the collection system
   (2) protect operating personnel
   (3) protect the treatment plant
   (4) meet effluent or stream standards.

6. Companies subject to industrial waste control can be placed in four general categories:
   (1) those producing wastes prohibited from sewers.
   (2) those producing wastes limited as to concentration before discharge to sewers.
   (3) those producing wastes limited as to both volume and concentration before discharge to sewers
   (4) those producing wastes limited as to concentration as they arrive at sewage treatment plants

7. The determination of sewer service charges and surcharges requires accurate gaging, sampling, and laboratory practices.

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Sewer Construction in Salt Lake City

by RAY DAY
Technical Writer, La Canada, Calif.

■ GROUND WATER, boulder-studded ground, financing problems and major contract lettings have featured one of the biggest sewage system undertakings of the Rocky Mountain west in Salt Lake County, Utah. In Salt Lake City's residential areas which extend to the east and south, contractors working under really tough construction conditions put the finishing touches on a 250-mile, $8,000,000 sanitary sewer collection system.

Designed by Caldwell, Richards & Sorenson of Salt Lake City, the project was paid for by taxation and revenue bonds. The latter paid for most of the main lines. Sewer taxation in Utah was previously authorized by that state's legislature, which set a three-mil levy to help finance construction. Authority to create sanitary districts extends as far back as 1957.

Salt Lake County's sewer problem is directly attributable to Salt Lake City's steady growth. There are estimates that Utah's capital city will reach 1,000,000 population by 1965. While that may prove to be a bit high, engineers do know that much of the population overflowed beyond the city limits into the County, east and south on flat benches just below the mountain fringes. Even as the system was being designed, growth factors were under almost constant revision upward.

Organizing for the big construction job, several Sanitary Sewer Districts were created, of which No. 1 was the largest. Strategically placed sewage treatment plants, and various types of sanitary sewers ranging from 42-inch diameter reinforced concrete pipe down to 4-inch laterals make up the system. A field office was established as close to the population centers as possible so that property owners could fill in the necessary application forms with a minimum of delay or trouble. This one precautionary piece of good engineering public relations did much to reduce public resistance to the location of necessary sewage treatment plants. And it made the public more tolerant of street congestion as construction got under way.

Job Problems

In some respects all the contractors faced almost identical construction problems. Excavation difficulties, formations, material supply, job organization and public relations were very similar. While the over-all system was sprawling and complex, the engineers broke it down successfully into many smaller contract jobs, all with a certain sameness.

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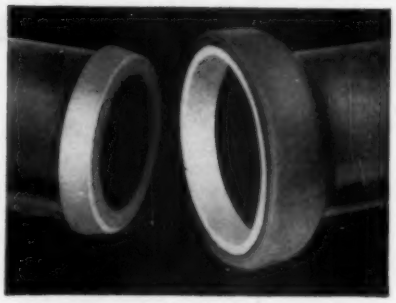


More than 200 major installations have been completed with outstanding results since Amvit Jointed Clay Pipe was introduced in 1955.

Such pioneer cities as Ann Arbor, Michigan, Dayton, Ohio, Camden, New Jersey have installed their second and third Amvit sanitary lines.

A mechanical joint designed for quick, low-cost installation, Amvit* will give you lower cost-in-place. Here's how:

1. QUICK INSTALLATION SAVES LABOR

No other materials such as caulking, joint compound, hot pots, or ladles are needed to make the Amvit joint. The joint is on the pipe delivered to the job ready for use. Just push the pipe together and the joint is complete.

2. IMMEDIATE BACKFILLING

You can backfill as soon as the line is completed. Barricades can be removed and streets opened days sooner.

3. QUICK TESTING

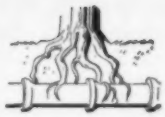
No need to wait days to see if a line has passed test. A look at the completed joint will tell. Thus, engineers can inspect and accept the line allowing the contractor to receive payment quicker.

4. CONTROLS INFILTRATION

Field tests from completed installations show that infiltration can be definitely controlled. Engineers can, thus, reduce infiltration specifications, use smaller diameter pipe and save in material cost.

5. ROOT PROOF

Amvit is a compression joint on the ball and socket principle. The surfaces of both bell and spigot are in uniform compression preventing root penetration.



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The design of the joint assures that the pipe is self-centered at all times. This gives perfect alignment and self-cleansing. Because the joint is really tight, no foreign matter such as dirt, sand and stones can possibly enter the line.

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HOW TIGHTLY the average job was closed up from start to finish is shown where an Allis-Chalmers HR-5 and Northwest 25 teamed up on one of the locations.

One of the most acute construction problems, from the contractors' viewpoints, was the necessity for keeping the jobs closed up much tighter than real efficiency would justify. It was the rule, rather than the exception, to see construction work active in an area from 200 to 350 feet long. By keeping the work tightened up in such a short area, there was less open ditch for children to fall into; less street congestion and dirt to play havoc with property owners living nearby. But it was necessary, in order to achieve such a tight job, to have backfill equipment standing by, on all the contracts, on approximately a 50-per-cent effective working basis.

Ground formations were typical of the alluvial fan which spreads out below the base of the mountains and slopes off gently toward Great Salt Lake. Excess irrigation over the years, when the area was agricultural, had raised the water table. Thus it was that the sewer system in many cases lay nine feet below the water table. That created a dewatering problem, along with the necessity for leakproof joints in the pipelines.

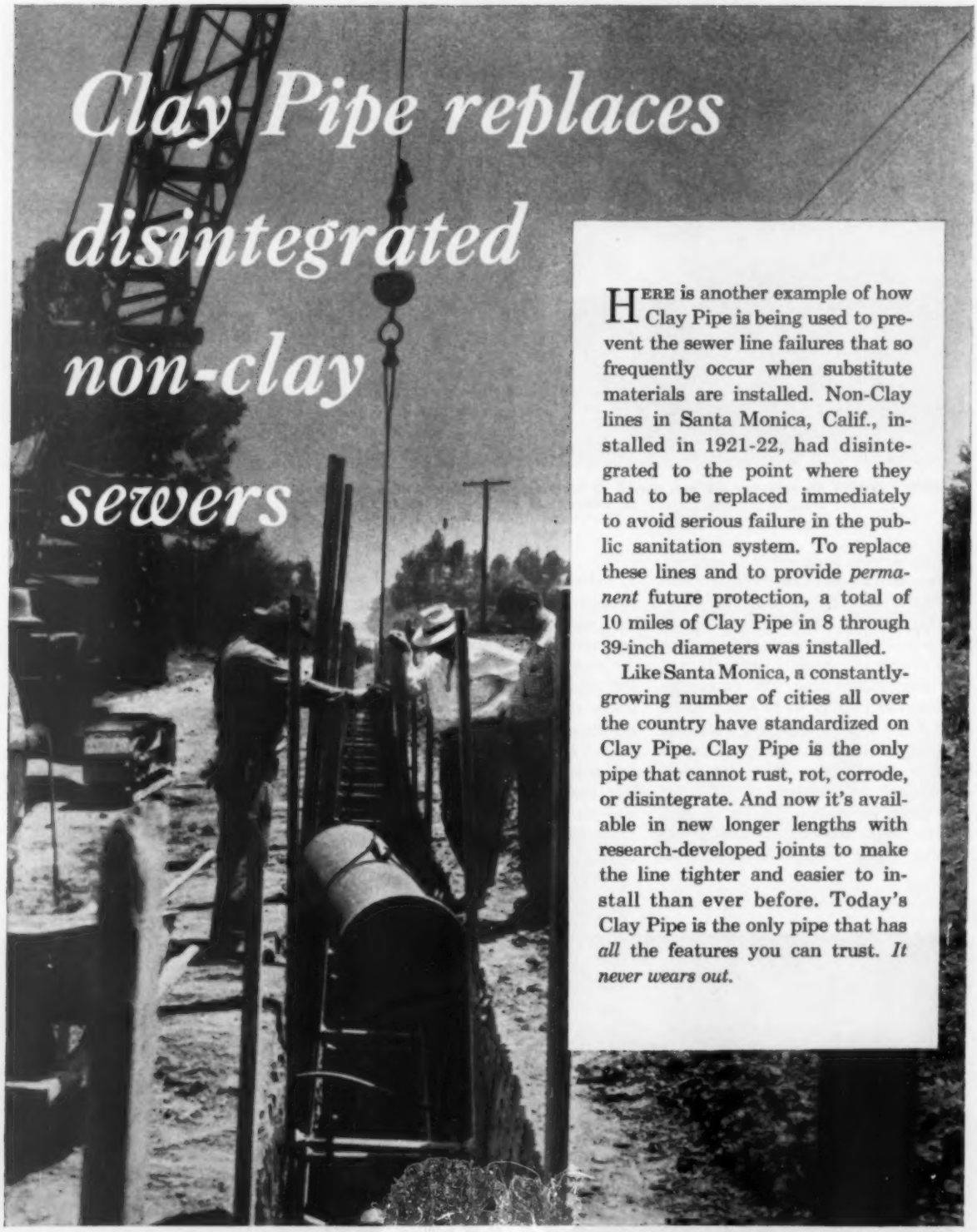
Other problems centered around a very tough excavating condition. A large part of the area was once covered by a glacier, which displaced large quantities of material as it moved. Huge boulders were ripped out and rounded as they traveled under the glacier toe. There has also been some cementation in the finer gravel, over the ages, all of which made for hard excavation. Other formations included hard clays, sand, and muck.

While specifications set forth a uniform standard of workmanship, the contractors were given all possible latitude on methods. Maximum infiltration criteria were set up for all types of pipe: vitrified clay, concrete, Transite. The major portion of the new system consisted of heavy-duty reinforced-concrete pipe, with a ring of jute and hot asphalt poured to create a tight water seal. This type of joint was believed to be the best balance between construction speed, economy, and minimum infiltration danger.

EXCESS MATERIAL is loaded on a Ford truck by an Allis-Chalmers HD-5 shovel.

Typical Contract Work

One of the typical construction contracts was held jointly by Tiago Construction Co. of Salt Lake City and Schmidt Construction Co. of Grand Junction, Colorado. It called for 60 miles of main sewer line and



Clay Pipe replaces disintegrated non-clay sewers

HERE is another example of how Clay Pipe is being used to prevent the sewer line failures that so frequently occur when substitute materials are installed. Non-Clay lines in Santa Monica, Calif., installed in 1921-22, had disintegrated to the point where they had to be replaced immediately to avoid serious failure in the public sanitation system. To replace these lines and to provide *permanent* future protection, a total of 10 miles of Clay Pipe in 8 through 39-inch diameters was installed.

Like Santa Monica, a constantly-growing number of cities all over the country have standardized on Clay Pipe. Clay Pipe is the only pipe that cannot rust, rot, corrode, or disintegrate. And now it's available in new longer lengths with research-developed joints to make the line tighter and easier to install than ever before. Today's Clay Pipe is the only pipe that has *all* the features you can trust. *It never wears out.*

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PIPE SETTERS and dewatering pump work in between an International TD-9 with a rock, rake, which works backfill into trench, and a P&H hoe excavating in the background

about 40 miles of laterals. The job was spread out between Ninth Street East to Wasatch Boulevard, and lay north of 4000 South Street.

The pipe in this contract ranged from 8 to 18 inches in diameter, with 4-inch laterals. Average depth of trench was 11 feet, with a 20-foot maximum. Formations included hard clay, hardpan, cemented and uncemented gravel, and a long stretch of wet, waterlogged sand. The hardpan represented some of the most dificult digging on the whole project.

Tiago staffed up with equipment especially selected for fast work under difficult conditions. A Buckeye Model 407 ditching machine was picked for lateral trench work. In easier digging clays on the main ditch, a Buckeye 160 and a Parsons 310 Trenchliner shared the honors. In harder excavation, where hardpan and boulders were problems, a Northwest 25 and Bucyrus-Erie 15-B backhoe went to work. In the very toughest digging, two Bucyrus Erie 22-B's were used. These machines could reach down and scoop hard bottom from an 18-foot-deep ditch without excessive boom angle.

Other equipment brought in by Tiago included an Allis-Chalmers HD-9 with front end loader, a Hough Payloader, and three Allis-Chalmers HD-5G's. Purpose of this equipment was to load out excess dirt from excavation, to place backfill, and do odd cleanup jobs. Several Littleford asphalt kettles were also brought in for heating joint asphalt.

Tiago's production schedule called for about 350 linear feet per day per backhoe, with pipe laying to match. It was not an easy schedule, chiefly because of many intersecting utilities lines. But by locating these as far in advance as possible, and working the hoes right up close to each one, it was possible to get through with a minimum of trouble and delay. There were even a few places, where street

HALFTRACK MOUNTED HYDROHOE, working a lateral on a paved street, is usually used in muddy, soft areas.

EXCAVATING around an intersecting gas line was accomplished by a 15-B Bucyrus-Erie hoe.

pavements and utilities offered no problem, where production went up to double the schedule per unit.

Most of the main-line pipe for this job came from Utah Concrete Pipe Co. or Cen-Vi-Ro, an Idaho manufacturing company. Pipe deliveries were scheduled so that job storage would be held to a minimum. As the various machines excavated the trench, a small labor crew did necessary finegrading. Worthington and Gorman-Rupp pumps were used for unwatering, just ahead of the pipe laying operation.

As each pipe section was laid, a sealing rope was placed around the outside of the joint, the jute ring tamped in by plumbing tools, and hot asphalt filler was poured in. If rocks and boulders were contained in the backfill, the pipe was covered first with finer material brought up by front end loaders or selected with hand shovels by the labor crew. Backfill compaction was handled by flooding the material with jets, supplied with water from tank trucks.

Heavy Boulder Spread

Heaviest boulder excavation occurred in a 20-mile job, with pipe up to 15 inches in diameter, handled by Contractors Hilton & Carr Construction Co. Like Tiago's work, it, too, was organized to stay caught up in a relatively short distance.

Hilton & Carr used backhoes entirely for trench excavation. The company used a P&H 225-A, a ¾-yard Unit, and a small ½-yard Badger, manufactured by Austin Western. For lateral work, this contractor used two Schramm diggers on pneumatic compressor-type tractors. Dewatering on this spread was a first-grade problem, so Hilton & Carr used up to ten Gorman-Rupp and Worthington pumps.

For practically this entire job, excavation in very large boulders had to be battled through, almost foot by foot, as pipelaying crews with dewatering pumps stayed close behind. Many spots 50 feet long took over half a shift to finish, chiefly because excavation and dewatering were such difficult problems. Many sections wanted to cave, so bracing also had to be placed in accordance with State safety Codes.

Muck Problem Solved

One of the most unique excavating operations of the project was that of Kloepfer Construction Co., Logan, Utah. Over the years, Kloepfer has learned the importance of mechanizing to the hilt, and this job reached an unusual peak in that regard.

One of the most unique mechanization examples on Kloepfer's work was the mounting of a Bucyrus-Erie H3 Hydrohoe on a war surplus White halftrack. Kloepfer decided on the halftrack mounting because much of his work in recent years has been in the marshiest areas of Salt Lake County and City. His contract work on this project covered some of its most treacherous soft digging. But the halftrack mounting permits him to move in with the Hydrocrane and dig in spots which would mire an ordinary truck or crawler mounted rig. The halftrack mounting makes the machine float over the worst places.

Kloepfer used his Hydrohoe principally to mechanize lateral work. Up to now, most contractors used a great deal of hand labor on that operation. The Hydrohoe has eliminated all that; in fact, laterals which pass under sidewalks were dug successfully by Kloepfer's machine, without any hand labor whatever. Kloepfer likes to tell about one location where two telephone cables, four high-pressure water lines and one gas-main were located next to a sidewalk, all within a 25-foot distance. This entire excavation was made in about an hour, without using any hand labor whatever.

Kloepfer used a 24-inch bucket, built up to ⅜-yard capacity, on the machine. Should he ever want to put the Hydrohoe on a truck in the future, removal of ten bolts in the base lets it lift off for such conventional mounting. The machine has made 50-mile trips between jobs, however, on its halftrack mounting.

Another of Kloepfer's innovations was the use of a metal skip for bedding the gravel in the bottom of trenches, where cushion material was specified. Made from an old piece of curved sheet iron, the skip was built to hold a truckload of material. The skip is handled by backhoes, and the idea did much to help eliminate hand labor customarily used on that operation.

Other equipment on this spread included two 22-B dragshovels, an Austin-Western Badger, an International TD-9 and TD18, and a Cat D7 with backfilling dozer. An Austin Western motor grader also was used for backfilling, particularly on laterals. Kloepfer's spread was one of the few to be radio equipped for better communication. Motorola equipment was used throughout.

SPECIAL GRAVEL SKIP, handled by a 22-B backhoe, permitted gravel cushion material to be placed speedily and economically under the sewer pipe.

Completion of the sprawling sewage system will allow Salt Lake County to expand for many years to come, secure in its ability to take care of its problem. Pollution of nearby mountain streams has been eliminated, and since Salt Lake County streams empty into Great Salt Lake, that body of water also has been spared from pollution by the new works. The project was done efficiently and quietly to make a cleaner, better community in Salt Lake City's environs.

Personnel

Design engineering and supervision of the big program was under the general supervision of Alton H. Sorenson of Caldwell, Richards and Sorenson. Charles Kelly represented the firm as Project Engineer in the field, assisted by G. E. Torgersen.

On the contract spreads described in this article, Eldon Kloepfer ran his job personally, as did J. S. Hilton and Fredd Carr, Jr. on their work. Jack Cook was the superintendent on the Schmidt-Tiago joint venture. Individually and jointly, these men have created a badly needed sanitary sewerage facility for one of the most rapidly growing communities in the Rocky Mountain West.

Water Line Installation in North Ridgeville, Ohio

■ IN NORTH RIDGEVILLE, OHIO, extending the water supply facilities required the installation of 16 miles of six and eight inch pipe. The pipe was laid at a depth of 5½ feet in a trench 20 inches wide.

Trenching started in November and continued throughout the winter and spring in all kinds of weather. Soil conditions of every description were encountered, winter snows, frozen soil, rains and mud, hard clay and boulder laden ground.

As might be expected in any community, one of the problems was that of cramped quarters and the necessity for working close to trees, poles, fences and other surface obstructions. Subsurfaced obstructions were also encountered including house service lines, sewers and other utility lines.

To accomplish the necessary work and meet all of the conditions encountered the contractor on this job used a Cleveland Trencher Model 110 to obtain smooth full crawlers and low ground bearing pressure and a resultant ability to tread lightly on lawns and sidewalks. With this unit the contractor was able to meet the frequent necessity for raising and lowering the digging wheel to avoid obstructions.

The photo shows the machine at work in the front yard of a water customer.

Sewer Department Utilizes Hydraulic Crane

Fond du Lac, Wis. finds Hydrocrane versatile for crane and clamshell work

by HAROLD SMET

Supt. of Sewers, Fond du Lac, Wis.

■ MORE THAN 250,000 feet of sewers and lateral will be laid in Fond du Lac this year. This city of 30,000 population has a modern sewer department which employs a spread of mechanical equipment including a ⅝ yd shovel, a 1-yd shovel, a shovel loader, six dump trucks, and a Bucyrus-Erie H-5 Hydrocrane. This city has long been an advocate of mechanized equipment and before purchasing the Hydro-crane in 1957 used an H-3 model of the same machine.

Many Construction Problems

Among the problems of construction met by the sewer department are the laying of large sewer pipe and the handling of steel sheeting for shoring trenches. The steel sheeting is about 14 to 20 ft long and when six of them are handled together they weigh up to two tons.

Other operations by the sewer department include the putting down of gravel base in trenches and the adding of backfill sand. When wells in storm sewer pump houses require lowering, digging is done through the door or roof openings with a clamshell.

Because of its spread of equipment the sewer department is often called upon for jobs which are really outside of its function. Among these jobs have been: Setting a clarifier at the sewage disposal plant, setting a steel structure for the Electric Department, unloading steel plates for the Street Department, handling water mains during laying, dredging a city lagoon, and handling 18-in concrete sewer pipe for a new sub-division.

Versatile Tool

It has been found that one tool, the H-5 Hydrocrane is versatile enough to handle all of these various jobs. The H-5 boom telescopes from 24 to 36 ft and a ½ yd clamshell can be attached in minutes. Remote control makes it possible for the operator to drive the Hydrocrane truck from the cab when laying pipe. All of the H-5 functions are hydraulically powered and controlled. When operations are to begin, operator Charles Day has only to flick the controls in the cab and extend the four outriggers.

The City of Fond du Lac is one of a growing list of municipalities which own and operate construction equipment needed for water and sewer department operations. Among the types of equipment most used for these utilities are: Pneumatic tools, backhoes, bull-dozers, trenchers, payloaders, cranes, trucks, compressors, as well as pumps, graders, degenerators, drag lines, bucket machines, rollers, and power shovels.

EXCAVATED MATERIAL from a trench is recast by a ½ yd clamshell attached to Bucyrus-Erie H-5 Hydrocrane belonging to sewer department of Fond du Lac, Wis.

Relief Sewer Design and Construction

By WILLIAM A. MARCON
Project Engineer, Department of Public Works, Westchester County, White Plains, N. Y.

WHEN the Sheldrake West Branch Sewer, a part of Westchester County's intercepting sewer system, was built twenty-five years ago, it was considered expedient to temporarily utilize a considerable length of existing fifteen-inch vitrified clay sewer. It was the intention of the County to replace this section when the sewage flow from the twenty-four-inch pipe discharging into it approximated the capacity of the fifteen-inch. Population growth in the sewer district has reached a point where the smaller sewer is no longer adequate to handle increased flow. During wet weather and other periods of high flows, surcharging of sewers and flooding of basements have occurred.

The fifteen-inch sewer is located in the Town of Mamaroneck, N.Y., and extends from Rockland Avenue, approximately 2100 feet to Valley Stream Road, where it connects with the Sheldrake East Branch Sewer. Most of the sewer is laid in rock and is located in residential streets.

Various solutions were investigated to relieve the situation, and the following three methods appeared to be feasible:

1. The construction of a relief sewer at a higher grade than the existing fifteen-inch, but paralleling it about five feet away.

2. The replacement of the existing fifteen-inch sewer with a new and larger sewer, in the same trench and at the same grade as the fifteen-inch.

3. The construction of a new relief sewer in the same trench, directly above and parallel to the existing fifteen-inch, leaving the existing line in operation.

Because of the large amount of rock along the line, method 1, that of paralleling the existing sewer with a new line was rejected as too expensive. Extensive blasting would have been necessary and would have caused material damage to the existing fifteen-inch sewer and to the water, gas, and storm drain lines which underlie the narrow streets. Laying a new sewer by this method would have necessitated several relocations of utilities, and new house connections.

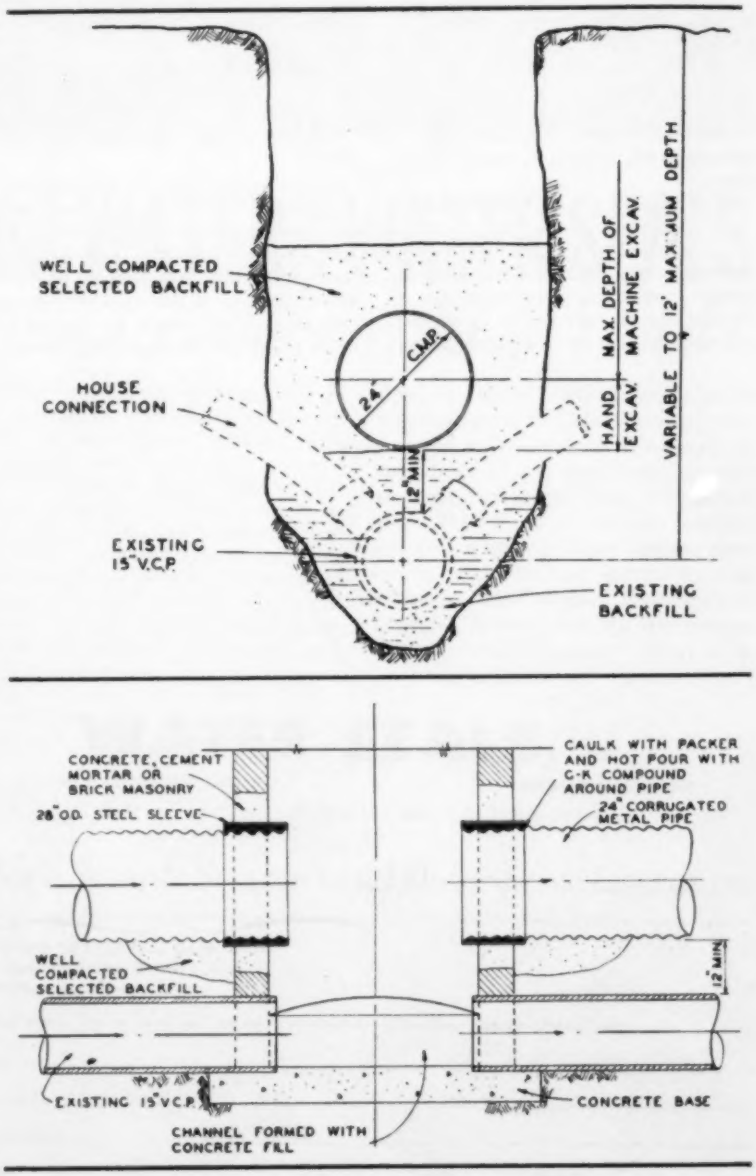
Method 2, that of replacing the pipe, appeared satisfactory except for the tedious and involved operation, during construction, of pumping sewage in a highly developed residential area, replacing all house connections, and widening the existing trench.

Method Economical and Convenient

Method 3, that of constructing a new relief sewer above the existing fifteen-inch pipe, although heretofore untried by the Department of Public Works, was agreed upon in view of its economy and the minimum inconvenience that it afforded the residents of the area concerned. A study was made of the possible construction methods and materials required.

A comparison of estimated costs for the three methods revealed that method 3 would be twenty and ten thousand dollars less expensive respectively than methods 1 and 2.

Twenty-four-inch diameter, coated



and lined corrugated metal pipe was selected for the relief sewer because of its light weight, long lengths and ease of installation.

As shown in Fig. 1, approximately one-foot clearance was allowed between the existing fifteen-inch pipe and the corrugated metal relief pipe. The distance was set to allow for clearance of existing house connections and also to prevent breakage of the underlying fifteen-inch line by excavating equipment. Machine excavation was permitted to within one foot above invert grade and hand excavation was required for the remainder.

Approximately 175 feet of the existing sewer is laid in the bed of the Sheldrake River. It was decided to replace the existing sixteen-inch cast iron pipe under the stream, in this section, with twenty-four-inch C. I., mechanical joint pipe in the same trench. Because this section was only three feet below the stream bed, cast iron pipe was selected to prevent flotation and reduce the possibility of damage from stream clearing equipment.

In general, the work progressed according to plan. The corrugated pipe was furnished in twenty-foot lengths with one foot, silo lug, connecting bands. Pipe laying was rapid due to the fact that no rock had to be blasted, and the excavation consisted of former backfill material. Also, the flexibility of the corrugated pipe allowed deflections to be made at certain joints to miss obstacles in the path of the pipe. The time-consuming task of making joints was greatly reduced by using twenty-foot lengths of pipe and silo lug connecting bands.

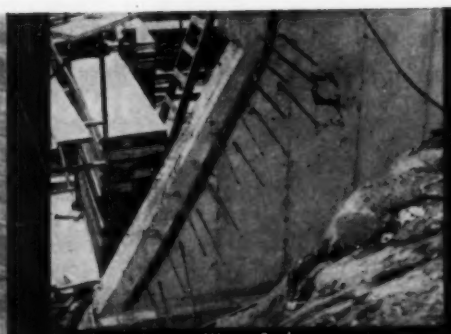
Connections at manholes were given special study. To avoid cracking the mortar at the connection, a somewhat flexible joint was required. This was accomplished by inserting a twenty-eight-inch diameter steel sleeve fifteen inches long and ⅜-in. thick into the manhole and mortaring it in place (see Fig. 2). The corrugated pipe was later inserted into the steel sleeve and caulked with a hot bituminous jointing compound. This type of joint allowed for slight settlement of the pipe without damage to the manhole or pipe.

Specifications called for a heavy bituminous coating on all corrugated metal and the repair of this coating wherever it was damaged by handling.

Our problem was to alleviate surcharging of the Sheldrake Sewer and the resulting flooding of cellars in the area. With the new design, when sewage rises in the manholes to one foot above the top of the existing fifteen-inch pipe, it will begin to flow to the next manhole through the twenty-four-inch relief pipe. Each section between manholes has a different slope, thereby producing different depths of flow. With the relief pipe in place, no manhole will surcharge above the flow line in the twenty-four-inch pipe, the elevation of which is below the danger point. Formerly sewage rose to the top of certain manholes and, in some cases, spilled out onto the surrounding ground.

This method, we believe, can substantially reduce the costs of relief sewer construction where existing sewers are laid in rock and where their capacities are inadequate. It is only suitable, however, where grades are relatively steep and where depths below basements are ample.

Frank Bracalello, Inc., of Scarsdale, N. Y., was the Contractor. The total bid was $58,991.57, which averaged about $28.00 per lineal foot. The final studies and design for this project were carried out by the author under the immediate direction of L. G. Rice, Consultant on design and construction, and under the general supervision of G. E. Griffin, Deputy Commissioner of Public Works in charge of the Sewer Division and Mr. James C. Harding, Commissioner of Public Works for Westchester County, New York.



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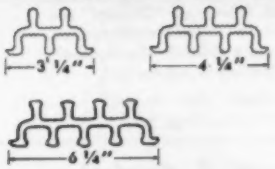

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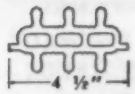
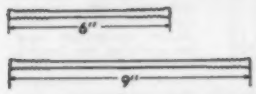


FLEXTRIP



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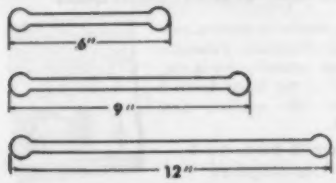

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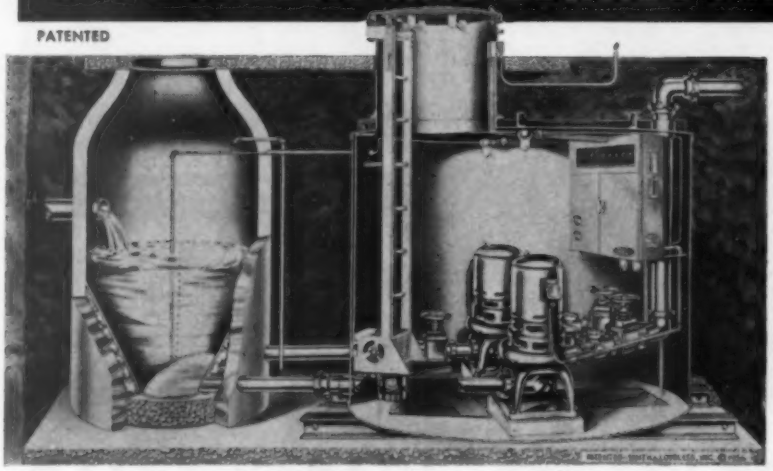

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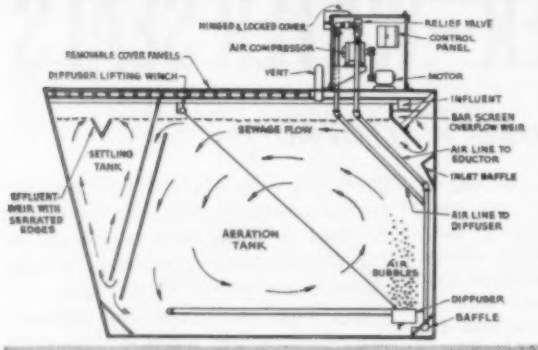

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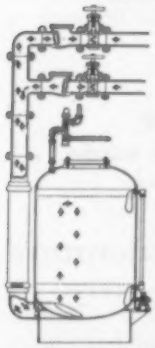

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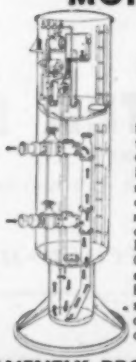

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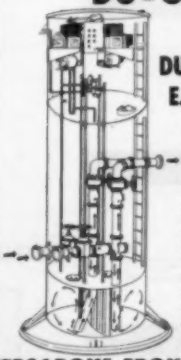
Smith & Loveless "DU-O-JECT" FACTORY-BUILT DUPLEX PNEUMATIC EJECTOR STATION



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Notes on Design of Sewage Lift Stations

By COMPERE LOVELESS
Smith & Loveless Inc., Kansas City, Mo.

THIS INFORMATION has been compiled from reference books as well as from observation of some better designed pump stations. Much of the material will seem elementary but it is offered with the thought it will be convenient as a ready reference.

Need For Pumping

1. Where the topography is such that good sewer grades are not possible with gravity flow, without excessive depth and with consequent high construction costs. The sewer grade is carried as low as is practical, then the sewage is raised by a lift station to bring the sewer close to surface again.

2. Where the sewer discharges into a river or other body of water with the hydraulic grade of the sewer below the river surface. In many cases such lift stations are only used during high water or flood conditions, and are by-passed most of the time.

3. Where the hydraulic grade is such that there is insufficient head for gravity flow through a treatment plant.

4. Where it is necessary to boost the sewage over a ridge through a long discharge line, or force main, to a point from which it will flow by gravity. Such force mains are generally of cast iron pipe of the kind used for water mains.

Types of Lift Stations

Wet Pit Pump Stations with sewage type sump pumps are sometimes used in the basements of buildings to serve fixtures too low for flow by gravity into the sewer systems. Most Board of Health rules will not permit the use of such equipment where reliability is important. This construction places the most important equipment right down in the sewage where it is subject to rapid deterioration of the bearings, shaft seal, etc., and the equipment is not accessible for maintenance.

Dry Pit Pump Stations offer the lowest cost per gallon of capacity combined with good reliability. Centrifugal sewage pumps require less space than pneumatic ejectors of comparable capacity. For average and larger capacities they are more efficient than ejectors and hence, require less connected horsepower and consume less electric power.

Pneumatic Ejector Stations utilize air pressure to produce pumping action. For rated capacities less than 100 GPM only an ejector can handle rags and large solids efficiently and reliably, and maintain adequate velocities in the fore main.

Sewage ejectors commonly cost more than pumps for a given capacity because more parts and fittings are required; also more room is required to house the equipment. The Smith & Loveless "Mon-O-Ject" and "Du-O-Ject" Ejector Stations eliminate the space problem by using the structure itself as part of the working equipment. These single and duplex ejector stations give all the advantages of pneumatic ejector stations at minimum cost.

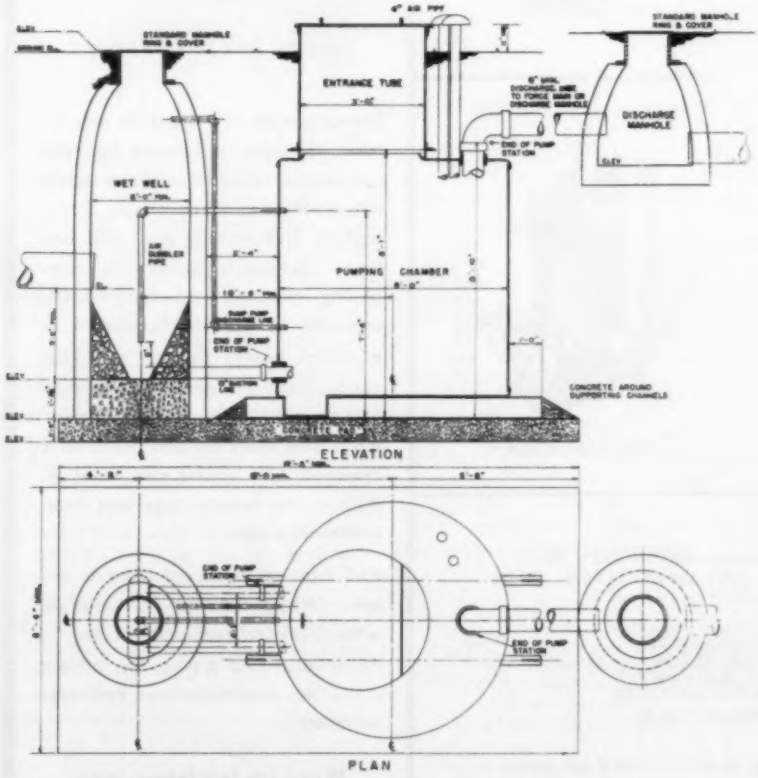

Fig. 1—DESIGN of factory-built underground sewage pump station

Determination of Pumping Rate

Most of the volume of sanitary sewage and industrial wastes originates from the water supply. Hence, any determination of needed pump capacity should start with the records for water consumption for similar areas of the city. Actual measurements indicate that sewage flow will normally vary from 70 to 130 per cent of water consumption. Therefore, designers often assume that the average (not peak) rate of sewage flow, including some allowance for ground water infiltration, will equal the average rate of water consumption.

The amount of ground water which infiltrates into the sewers through poor joints, cracked pipe, manhole walls, basement drains, etc., varies so widely that prediction is difficult. When available, local experience data are the best guide. Maximum infiltration rates of 50,000 gallons per day per mile of sewer are frequently encountered in well built sewers below ground water level. A common design allowance is 1000 to 2000 gallons per day per acre served, depending on the ground water level and condition of the sewer.

The maximum rate during the day is used to set the pump design capacity. For sanitary sewers in a resi-

for handling domestic and industrial wastes, pneumatic ejectors are better.. and..

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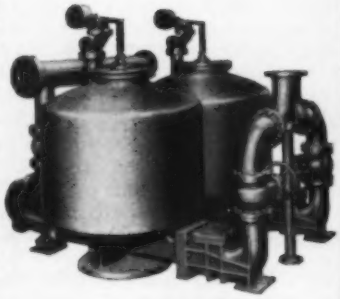
3. **Trouble-free.** Pneumatic ejectors have relatively few working parts which move neither fast nor far. Operation is positive. Maintenance problems are almost nonexistent.
4. **Handles solids easily.** Pneumatic ejectors will pass solids up to the size of the inlet and discharge valves.. minimum of four inches.



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2. Yeomans builds the only complete lines of pneumatic ejectors.. more than 100 sizes in three basic types . . the Shone . . the Expelsor . . and the Packex.
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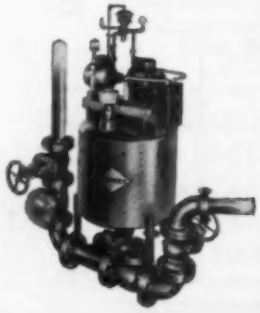

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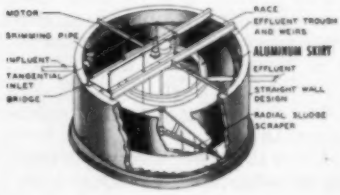

Removes more solids and elimates short circuiting

The aluminum skirt forms an annular race. Sewage introduced into this race spirals slowly down and enters the clarification compartment at the bottom. Diffusion is slow and uniform. Settleable solids are completely removed. Sewage moving upwards in the clarification compartment passes through a sludge zone. Here increased flocculation occurs. 70% Of the suspended solids and finely divided particles is removed. Oil, grease and scum remain in the annular race and enter a skimming pipe.

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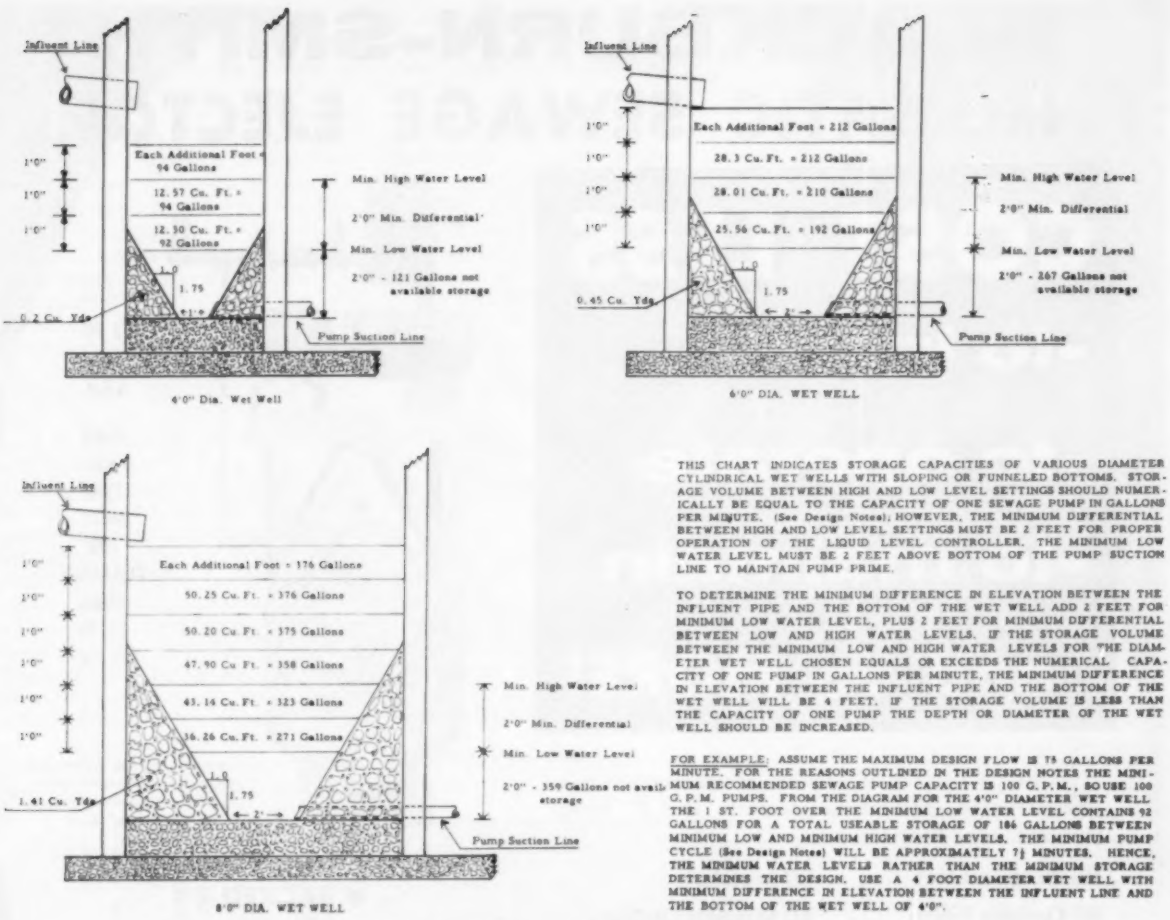
Influent Line
Each Additional Foot = 94 Gallons
12.57 Cu. Ft. = 94 Gallons
12.30 Cu. Ft. = 92 Gallons
Min. High Water Level
2'0" Min. Differential
Min. Low Water Level
2'0" - 121 Gallons not available storage
0.2 Cu. Yds.
Pump Suction Line
4'0" Dia. Wet Well
Each Additional Foot = 212 Gallons
28.3 Cu. Ft. = 212 Gallons
28.01 Cu. Ft. = 210 Gallons
25.56 Cu. Ft. = 192 Gallons
0.45 Cu. Yds.
2'0" - 267 Gallons not available storage
6'0" DIA. WET WELL
Each Additional Foot = 176 Gallons
50.25 Cu. Ft. = 376 Gallons
50.20 Cu. Ft. = 375 Gallons
47.90 Cu. Ft. = 358 Gallons
43.14 Cu. Ft. = 323 Gallons
36.26 Cu. Ft. = 271 Gallons
1.41 Cu. Yds.
2'0" - 359 Gallons not avail storage
8'0" DIA. WET WELL

THIS CHART INDICATES STORAGE CAPACITIES OF VARIOUS DIAMETER CYLINDRICAL WET WELLS WITH SLOPING OR FUNNELED BOTTOMS. STORAGE VOLUME BETWEEN HIGH AND LOW LEVEL SETTINGS SHOULD NUMERICALLY BE EQUAL TO THE CAPACITY OF ONE SEWAGE PUMP IN GALLONS PER MINUTE. (See Design Notes); HOWEVER, THE MINIMUM DIFFERENTIAL BETWEEN HIGH AND LOW LEVEL SETTINGS MUST BE 2 FEET FOR PROPER OPERATION OF THE LIQUID LEVEL CONTROLLER. THE MINIMUM LOW WATER LEVEL MUST BE 2 FEET ABOVE BOTTOM OF THE PUMP SUCTION LINE TO MAINTAIN PUMP PRIME.

TO DETERMINE THE MINIMUM DIFFERENCE IN ELEVATION BETWEEN THE INFLUENT PIPE AND THE BOTTOM OF THE WET WELL ADD 2 FEET FOR MINIMUM LOW WATER LEVEL, PLUS 2 FEET FOR MINIMUM DIFFERENTIAL BETWEEN LOW AND HIGH WATER LEVELS. IF THE STORAGE VOLUME BETWEEN THE MINIMUM LOW AND HIGH WATER LEVELS FOR THE DIAMETER WET WELL CHOSEN EQUALS OR EXCEEDS THE NUMERICAL CAPACITY OF ONE PUMP IN GALLONS PER MINUTE, THE MINIMUM DIFFERENCE IN ELEVATION BETWEEN THE INFLUENT PIPE AND THE BOTTOM OF THE WET WELL WILL BE 4 FEET. IF THE STORAGE VOLUME IS LESS THAN THE CAPACITY OF ONE PUMP THE DEPTH OR DIAMETER OF THE WET WELL SHOULD BE INCREASED.

FOR EXAMPLE: ASSUME THE MAXIMUM DESIGN FLOW IS 75 GALLONS PER MINUTE. FOR THE REASONS OUTLINED IN THE DESIGN NOTES THE MINIMUM RECOMMENDED SEWAGE PUMP CAPACITY IS 100 G.P.M., SO USE 100 G.P.M. PUMPS. FROM THE DIAGRAM FOR THE 4'0" DIAMETER WET WELL THE 1 ST. FOOT OVER THE MINIMUM LOW WATER LEVEL CONTAINS 92 GALLONS FOR A TOTAL USEABLE STORAGE OF 184 GALLONS BETWEEN MINIMUM LOW AND MINIMUM HIGH WATER LEVELS. THE MINIMUM PUMP CYCLE (See Design Notes) WILL BE APPROXIMATELY 7½ MINUTES. HENCE, THE MINIMUM WATER LEVELS RATHER THAN THE MINIMUM STORAGE DETERMINES THE DESIGN. USE A 4 FOOT DIAMETER WET WELL WITH MINIMUM DIFFERENCE IN ELEVATION BETWEEN THE INFLUENT LINE AND THE BOTTOM OF THE WET WELL OF 4'0".

Fig. 2—CHART of storage capacities for wet wells

dential area, the maximum is generally two to three times the average flow. For a very small residential area, it may be four times. For commercial areas, the peak may reach 150 per cent of the average. For industrial areas it will generally be somewhat less. Most text books and health department standards recommend an assumed design flow of 250 gallons per day per capita for normal residential areas which have a water consumption of 60 to 125 gallons per capita per day. When sewers are below the ground water level an allowance for infiltration should be added to this peak figure at the rate of 1000 to 2000 gallons per acre per day.

Assuming 100 gallons per capita per day average flow, four people per house and a peak flow of three times the average, *a good rule of thumb* in determining maximum flow, is to allow one gallon per minute per residence for the average sub-division. This includes a 20% addition for infiltration. Thus, for 100 residences use two pumps or ejectors, each rated 100 GPM. For larger areas, see table below.

No. of Houses*	GPM Firm Capacity per house
30-200	1.0
250-400	0.9
450-600	0.8
Over 600	0.7

*Assume 1 house equals 2 apartments with 2 people each.
*Assume 1 house equals 4 trailer or motor court units.

Lift Stations are also used to handle storm water from highway underpasses, low intersections, parking lots and similar limited areas.

For storm water flow the rate is best estimated by the formula

$$Q = \frac{CiA}{43{,}200}$$

where Q = Flow in cubic feet per second
A = Drainage area in square feet
i = Average intensity of precipitation in in. per hr
C = Coefficient of run-off

The coefficient of run-off will vary with the duration of rainfall at the assumed rate, the condition of saturation from previous rains, the kind of surface, and the time required for flow to reach the drain from the farthest point.

Commonly, C will vary from 0.6 to 0.95 for impervious surfaces, or from 0.2 to 0.60 for pervious surfaces. (Note: Because 1 acre = 43,560 square feet the above formula is also given as Q = CiA where A = area in acres).

Determination of Pumping Head

It is important to make an accurate determination of the pumping head. With pumps, any appreciable error in head calculation will result in a variation of capacity of equal or greater magnitude. For small capacities a 10 per cent error in head will commonly result in over a 25 per cent increase or decrease in capacity. It is also important to remember that sewage pumps bought for small capacities, say 100 gpm, are operating very close to their shut-off (or maximum) head. Thus, it is particularly important to determine accurately the static lift. The use of an engineer's

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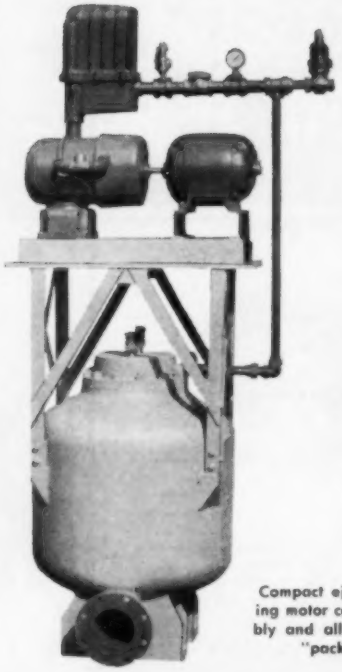

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level is recommended.

A pneumatic ejector using piston type compressors is less affected by errors in head determination. A 20% error under average conditions will produce less than 8% error in capacity required. Rotary compressors, however, are subject to a rapid increase in horsepower required, as well as overheating problems if the pressure exceeds the design head. So rotary compressors should be used with caution.

The total dynamic head (TDH) is the sum of the following:

1. *Static lift,* which is the vertical distance from the water level (generally the low water level) in the sump or wet well to the water surface at the outlet of the force main.

2. *Pipe friction* in the suction and discharge lines. (Consult charts for converting valves and fittings into equivalent lengths of straight pipe, and for determining friction loss for various sizes of pipes.)

For pneumatic ejectors, the inlet check valve is closed during ejection. Compute the friction loss only from the receiver, or "pot", to the force main outlet. Check separately to be sure that losses in the inlet line and fittings are not too great for gravity flow with the sewer grade available. Pneumatic ejectors discharge at twice their rated capacity, so double the rated flow before entering the friction loss charts.

The velocity head ($V^2/2g$) which is the energy possessed by the water because it is in motion. For velocity of 8 feet per second the velocity head amounts to 1.0 feet. Quite commonly this factor is small compared with the total head. Since force mains commonly discharge into a gravity tile sewer through an open transition channel in the bottom of the connecting manhole, most of the velocity head is recovered. As a result, it is frequently omitted from the head calculations.

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Selecting Pipe Size

If the pipe line is too small, excessive friction losses will result. Also, excessive velocities will accentuate any difficulties with water hammer or surge problems since the maximum pressure so developed varies directly with the initial velocity. (See the section on "Water Hammer.")

If the pipe line is too large it will cost too much. For handling sewage a minimum velocity of 2.5 ft per sec is required to prevent solids from depositing in the bottom of the pipe. Since most house connections are 4 in., both suction and discharge lines should be 4 in. minimum.

It will frequently be found that a pipe size adequate for one pump alone will deliver little extra sewage with the second pump also in service. This is not too important since the pump sizes are normally selected so one pump can handle the maximum flow.

Sometimes two discharge lines are provided; one to route the sewage to the treatment plant, another to some stream or ditch for emergency use, or for use during periods when adequate stream flow exists for disposal by dilution. When two force mains are provided a careful check of operating head conditions for both routes is necessary to insure that the pumps will operate satisfactorily for either. The use of a pump with a steep head capacity characteristic, such as the Fairbanks-Morse bladeless pump, helps to minimize such difficulties. It may be desirable to use a smaller size pipe for the route with the lower static head thus increasing the friction head and maintaining an adequate total dynamic head to avoid noisy operation.

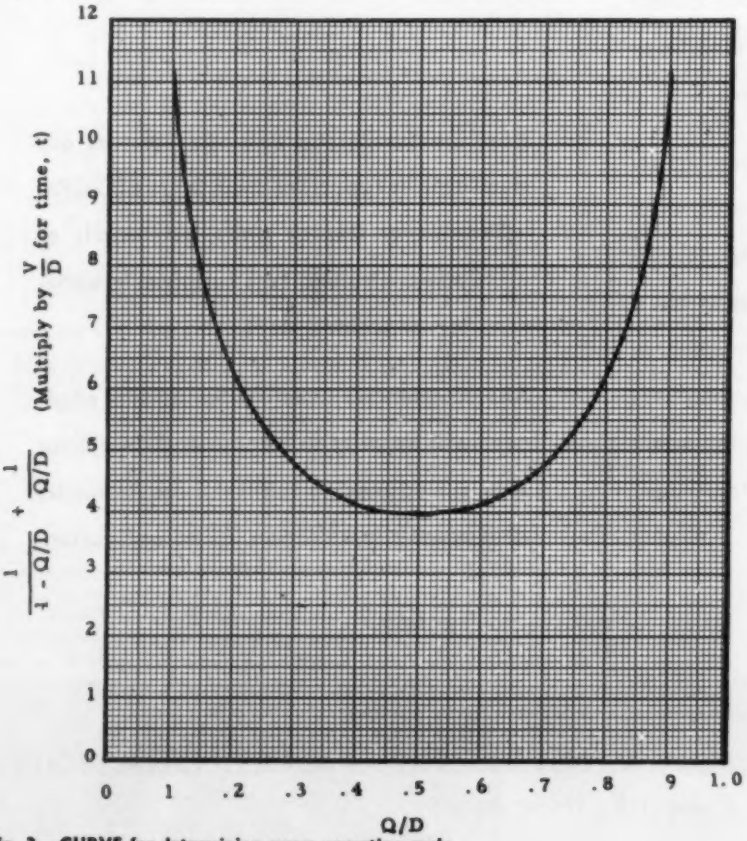

Fig. 3—CURVE for determining pump operating cycle

Water Hammer in Force Mains

The analysis and formulas for water hammer found in most handbooks do not apply to pump stations because they are based on a situation where the flow is interrupted at the outlet end of the line. For a pump station, however, the interruption of flow results from shutting off the pump at the inlet end followed by slamming of the check valve when flow reverses. When the pump stops the entire mass of water in the suction line, pump and discharge line is free to continue in motion under its own momentum until the column comes to rest and then starts to travel in the reverse direction. It is the sudden closing of the check valve which generally causes water hammer trouble in pump stations. If the valve is of a type which closes quickly before any reverse flow takes place the pressure increase from the returning wave will be relatively small. Should the valve stick, however, and then

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- No dangerous, unhealthy gases
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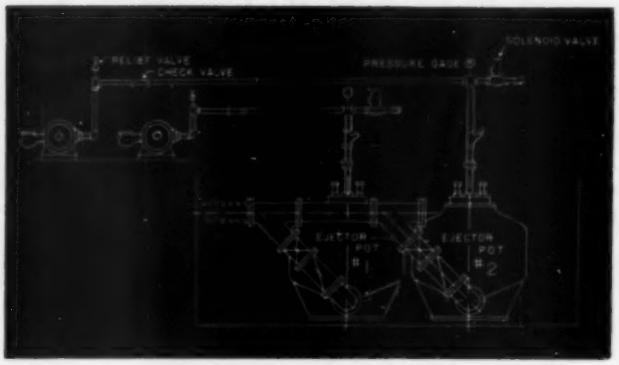

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slam after high reverse velocities have built up (such velocities can be much larger than those produced by the pump) then the resulting pressures may rupture the pipe or valve. Springs or weight loaded check valves may be desirable on long lines and/or for high heads. Generally, however, water hammer is not a problem in sewage pump stations.

Size of Pumps or Ejectors

Because house connections are 4 in., the smallest pump (or pipe) size should be 4 in. Since the velocity must be 2.5 ft per sec or more, it follows that the very minimum pump capacity should be 100 gpm (which produces 2.55 feet per second in a 4-in. pipe). Since a 3-in. diameter solid can traverse the bends and rough joints of a 4-in. tile pipe line the sewage pump should be capable of handling at least a 3-in. solid.

Pumps which will pass 3″ solids will have their peak efficiency at 400 to 800 GPM depending on speed and impeller diameter. Such pumps are inefficient at small capacities and are operating close to their shut off, or maximum head. Therefore, ejectors are best for small capacities, especially capacities below 100 GPM. Pneumatic sewage ejectors discharge at twice their rated capacity because they only operate one-half of the time. The normal cycle allows 30 seconds to fill the receiver, or "pot", and 30 seconds to empty it. Therefore, a 50 GPM ejector will produce a velocity of 2.55 feet per second in 4″ pipe. This is the preferred minimum rating for ejectors although 30 GPM ejectors are sometimes used because they will handle large solids, even though they produce only 1.53 feet per second velocity in 4″ pipe.

Motor Size and Type

Three phase current is always superior to single phase because of greater dependability of three phase motors. The voltage should be 220 although 440 can be used. Single phase motors larger than 5 hp should never be used. For single phase jobs particular care should be used in checking with the power company regarding wire sizes and transformer capacities. Low voltages at the end of long single phase lines are a common cause of difficulty. Where possible, two sources of electric power are desirable to insure continuity of service.

Pneumatic ejectors with an adequate air storage tank require approximately half the motor horsepower of ejectors without air storage. Use an air storage tank in outlaying stations to hold down the connected load.

Design of Wet Well

The Wet Well or receiving manhole should be as small as possible to prevent septic action during periods of very low flow. However, the wet well must be large enough to allow at least 3 to 5 minutes to elapse between successive starts of a pump to prevent overheating of the electric motor and control. The bottom of the wet well should be sloped as indicated in Fig. 1 to eliminate the possibility of sewage solids settling out and becoming septic. The volumes resulting from the flat slopes intersecting a cylindrical sump are complicated to compute, therefore, Fig. 2 shows a tabulation of storage volumes for 4, 6 and 8 ft diameter wet wells so constructed.

Normally, a wet well is constructed of brick or of curved concrete blocks of the type available for either 4 or 6 ft manholes. The blocks for 6 ft manholes can be used very successfully to build an 8 ft diameter wet well by opening up the inner joints. The inner surfaces of the concrete blocks should be parged with cement mortar and given a bituminous coating to protect the concrete from acids in the sewage. See Fig. 1 for the general construction of the wet well and its relationship to the pump station. Note that the elevation of the bottom of the wet well is determined by the elevation of the invert of the lowest sewer flowing into the wet well *and* by the vertical distance below the invert required for adequate storage to permit a 4 minute operating cycle.

It can be demonstrated mathematically that the length of the operating cycle has a parabolic variation and that the shortest operating cycle occurs when sewage is flowing into the wet well at one-half of rated pump capacity.

If D = Rated pump delivery in gpm
V = Storage volume between high and low levels in gal
Q = Inflow to wet well in gpm
t = Total time between successive pump starts (operating cycle)

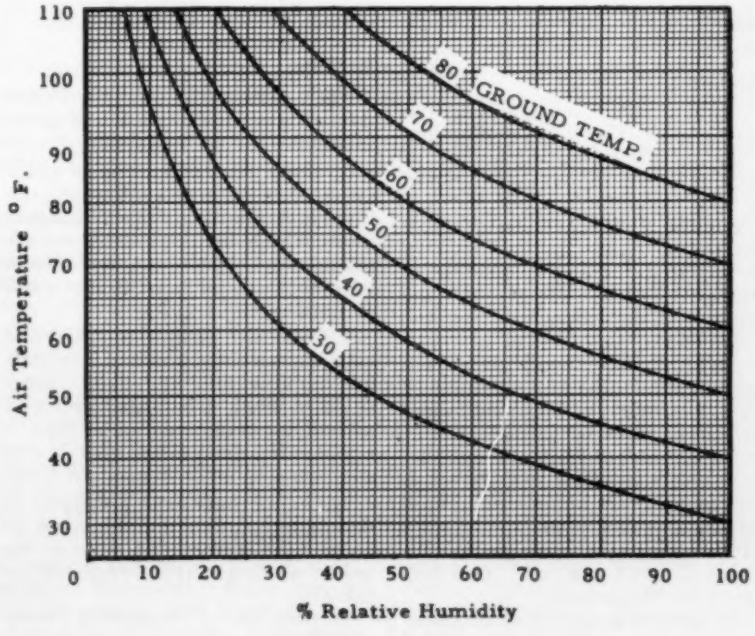
$$\text{then } t = \frac{V}{D-Q} + \frac{V}{Q}$$

$$\text{and } t = \frac{V}{D}\left[\frac{1}{1-\frac{Q}{D}} + \frac{1}{\frac{Q}{D}}\right]$$

Where V and D are constant for any particular installation.

To obtain the operating cycle in minutes for a particular installation multiply the vertical reading from the curve in Fig. 3 by V/D.

If the storage (V) equals the rated pump capacity (D) and if sewage is flowing into the clear well at one-half the pump capacity (Q/D = 0.5), then it would take two minutes to pump from the high level to the low level. It would take two more minutes to refill the wet well to the high level. Thus, the cycle is four minutes. As the above curve shows, this is the *minimum* cycle. For any other combination of inflow and pumping rates the cycle is longer. It is interesting to note from the above curve, however,



that for such wide variations of inflow as 0.2D to 0.8D the operating cycle only varies from 4 to 6¼ minutes.

Since a 4 minute cycle is a reasonable minimum for reasonable electrical control life it follows that: *The minimum storage required in gallons is numerically equal to the pump rated capacity in gallons per minute.* An examination of Fig. 2 will show that a standard four foot diameter manhole is big enough for most small systems because only 100 gallons of storage is required for the minimum size (100 gpm) pump recommended. Note that the figure is only the minimum and more storage is desirable when available at little or no additional cost. Actually, it may *not* be possible to use the minimum so determined because there must be at least a two foot differential between the high level and low level settings of the low level pump. The high level pump settings normally overlap the low level range, being at least 6 inches to 1 foot higher in each case.

It is impractical to provide storage in the wet well for prolonged power outages or excessive sewage flows. It is much cheaper and more dependable to select each pump to handle maximum flow. Where possible a gravity overflow line from the wet well to some water course is a very desirable feature. Such an overflow line automatically protects basements from flooding or prevents other nuisances during power failures. If the possibility exists that high water from such a water course can back up into the wet well, a flap gate or check valve should be incorporated in the line.

Flotation

Any structure extending below the ground water table, or extending into a fluid soil must be checked to be sure that buoyant forces do not exceed the total downward forces.

In most locations a factory-built underground pump station requires no special anchorage or loading to overcome buoyancy. The weight of the station, plus the concrete between the I beam skids, plus the soil on top of the main chamber, will exceed the buoyant forces. Special care should be taken, however, in locations where the station is to be located in very fine sandy soil which is, or may become, saturated. Such soil, known as "quicksand", can become very fluid and can flow like water.

It is easy to calculate the balance of forces when the soil conditions have been determined.

The upward acting forces are calculated as follows: In coarse sand, or gravel, or stable soil, assume the buoyant force is equal to the weight of displaced water (62.4 pounds per cubic foot) for all parts of the structure below the maximum anticipated ground water table. In quicksand assume the buoyant force equals the weight of the displaced soil, say 100 lb per cu ft.

Downward Forces

For unstable soils, like quicksand, disregard the weight of the soil on top of the station. For all other soils, assume that the full weight of dry soil is effective over the net top area of the main chamber.

For saturated soils, assume that the effective weight of the soil is the dry weight, less the weight of an equal volume of water. For most soils you can assume (100—62.4) or a net effective weight of 37.6 lb/cu ft.

Add the forces so calculated to the gross weights obtained from the Sales Representative. If the sum of the downward forces exceeds the sum of the buoyancy forces, obviously the structure will not float.

Note that the calculations ignore such *added* restraining factors as skin friction between the structures and the soil, adhesion between the concrete base and the leveling concrete, shear between overburden and adjoining soil, etc.

If the sum of the downward forces does *not* exceed the buoyant forces, anchor the station to the base slab and include its weight in the above calculation. Such additional concrete has an effective weight of (150—62.4) = 87.6 lb/cu ft in water, or (150—100) = 50 lb per cu ft in "quicksand".

Summary

For a satisfactory pumping station the following points should be borne in mind:

1. Use a "dry pit" pump or pneumatic ejector station. Wet pit stations with suspended pumps hanging in the sewage are not reliable and are not permitted by the Board of Health in most places for any but very small or temporary service.

2. Use two pumps or pneumatic ejectors, each of which is adequate for maximum flow. For smaller plants a single pneumatic ejector is sometimes permitted. Even then a standby air compressor with motors and controls is sometimes required.

3. Use an automatic alternator to distribute the wear on the pump or compressor motors and to keep the motor windings dry by frequent operation.

4. Provide a dependable sump pump with maximum protection against flooding from the sump pump discharge line. If possible, carry the discharge above high water in the wet well. Use two check valves if this cannot be done.

5. Control Humidity—Any underground structure, whether of concrete or steel, in most parts of the country is subject to condensation problems during part of the year. From about 6 feet underground down to the maximum depth practical for pump stations of this type, the ground temperature will be almost constant the year around. In the vicinity of Kansas City the ground temperature is about 52° F. When the outside air temperature is above the ground temperature it will be cooled when it comes in contact with the station walls. The reduction in temperature will raise the relative humidity, possibly to 100 percent. When the humidity of the cooled air does reach 100 per cent then condensation will occur on the cold surface, and the temperature at which this occurs is termed the "dew point".

Figure 4, together with local weather information and ground temperature, will enable the engineer to determine the seriousness of the problem. If the air temperature and the relative humidity intersect above the ground temperature line, then condensation will take place on the floor and walls of any underground structure.

In most parts of the country it will be necessary to combat humidity introduced with the outside air. In all parts of the country mechanical pump shaft seals are needed to keep out excess humidity from shaft leakage. A refrigeration type dehumidifier should be mounted in the air inlet duct so arranged that air is drawn through the dehumidifier from the outside whenever a pump is running. This fresh air is to remove motor heat and to ventilate the station periodically.

When no pumps are running, the air within the station should be recirculated automatically to dehumidify it before it cools. The dry air will absorb any moisture in the sump. Such dehumidifiers with sealed motor-compressor units are very dependable and long lived. The dehumidifier makes a properly built underground pump station superior to any other construction because of uniform temperature (from the ground) and uniform dryness.

6. Protect the steel structure inside and out against corrosion. Experience indicates that mill scale should be removed and the surface prepared by sand or shot blasting. The best coat-

ing available is an epoxy resin coating. This is an exceedingly adherent, tough and chemically inert plastic of the thermal setting type.

As an added insurance magnesium anodes or a DC rectifier system should be used for cathodic protection. Sufficient coatings and cathodic protection are installed on Smith & Loveless underground pumping stations to protect the structure from corrosion in average soil for 50 years minimum.

7. Provide double mechanical seals on the pumps in place of stuffing boxes, with clean sealing fluid between the seal surfaces at a pressure higher than the maximum sewage pressure. While many manufacturers make good sewage pumps, *no* sewage pumps have a completely satisfactory packing box. All sewage contains gritty solids. Leakage of sewage through the packing box permits such solids to cut out the packing and more important yet, the shaft or shaft sleeve next to the packing. After the shaft or sleeve wears the leakage increases.

Many attempts have been made to prevent leakage of sewage through the box by placing a lantern ring between several layers of packing and by then introducing clean water or lubricant under pressure higher than the sewage pressure. Such efforts result in improvement but not in a satisfactory solution to the problem. Even when handling clean water or clean oil or clean grease the packing *does wear!* The clearances on the shaft increase and leakage results with consequent accelerated wear!

Generally, the pressure or volume of sealing fluid is not adequate to maintain a pressure higher than the sewage pressure so sewage leaks up the shaft, mingles with the sealing fluid and passes out into the station. If higher seal fluid pressure is provided to prevent this, excessive seal fluid is used at high expense and with the seal fluid leaking into the station. The fact all of the seal fluid has been used up may not be discovered immediately—and excessive wear will result. This leakage of smelly, corrosive sewage is very undesirable in any pump station.

The double mechanical seal, in contrast, is almost completely free from leakage. One seal surface is of stainless steel or similar hard, corrosion-free material. The other is of a self-lubricating material such as carbon. Two such combinations are provided with seal fluid under pressure between them for cooling and lubrication.

Any leakage is of clean, non-abrasive sealing fluid cut into the sewage or out into the air. For a properly installed seal in good condition such leakage is practically nothing. As wear of the seal takes place, the seal automatically takes up the wear as the spring loaded surfaces move together.

The use of mechanical seals installed in this manner keeps the pump chamber clean and dry.

8. Provide an automatic control system for the pump which cannot be clogged by grease accumulation (as can a float system), or cannot be clogged by sewage solids or debris (as can a compression pipe type of air actuated control). This latter type has the further disadvantage of being very hard to adjust and to keep in adjustment because of the need for a delay cycle to recharge the compression pipe on each cycle to prevent water logging.

Experience has shown that the most dependable system is the air-bubbler system. This system includes a compact air compressor with built-in pressure control and storage tank. The air goes through a needle valve with automatic differential pressure regulator to insure constant flow by providing a constant pressure differential on the orifice. A visual flow meter provides a quick visual check on this air flow. The air discharges through a corrosion resistant line into the sewage below the low water level. The amount of submergence of the end of the line determines the back pressure. This back pressure is measured by sensitive pressure switches of the Bourdon tube type with magnetically actuated mercury tubes. The constant flow of air out of the end of the bubbler line keeps sewage from clogging the line. While sensitive, it is easy to adjust with completely independent high and low level adjustments for each pump.

9. For low pressures, rotary compressors are often used. Rotary type compressors require the addition of oil to the air to lubricate the sliding blades, and an oil recovery system to hold oil consumption down to a practical amount. Air cooled rotary compressors are not suitable for continuous service except in small sizes and/or at very low pressures. Hence, they should not be used with air tanks because of the danger of a compressor running continuously in such service, especially if it serves two sewage receivers.

For 20 ft or greater lift, the piston compressor will generally give lower connected horsepower, better service with air cooling, and lower maintenance. Also, the piston type compressor has no lubrication problems. For any application using an air storage tank the piston type compressor will prove superior for the same reasons.

All piston type compressors should have high torque motors or unloaders to permit them to come up to speed with minimum delay. The use of a Burgess snubber on the air intake of either a piston or rotary compressor will greatly reduce the noise level.

10. To hold the sewage receiver to a reasonable size, it is commonly designed with storage equal to its rated capacity in gallons per minute. As a result, when operating at full capacity, it has 30 seconds to discharge. For individual units with one compressor connected directly to one receiver this means that the compressor must start every 60 seconds. This is severe service which requires that conservatively rated starters and high starting torque motors be furnished. Single phase motors are especially vulnerable in such service.

11. An air storage tank of adequate size will cut down on the frequency of compressor operation. More important, it will cut the connected horsepower in half because provision for storing air makes it possible for the compressor to run continuously rather than half the time during operation at full rated ejector capacity. There is little point in storing much more air in the receiver than is required for discharging one-half of the storage in the receiver because the compressor will furnish the air for the other half during the discharge part of the cycle. It is not possible to store enough air for any useful period of operation in case the compressor fails. Since the automatic controls are normally electrically operated there is no point in storing air to take care of electric power outages.

If an air tank is used it need be only large enough for one receiver because if both receivers operate, the compressors will both operate. Together they can discharge the receivers alternately without any air storage. The air compressors should then be controlled by pressure switches on the air tank so arranged that one cuts in at the minimum pressure required. The other should operate on a close differential, starting almost immediately when air is withdrawn from the storage tank. In this way one-half of the air for ejecting the sewage will come from the compressor and one-half from the storage tank. Since only one will normally automatic alternator should be prooperate under such conditions, an vided to equalize the wear and to double the minimum operating cycle for each compressor.

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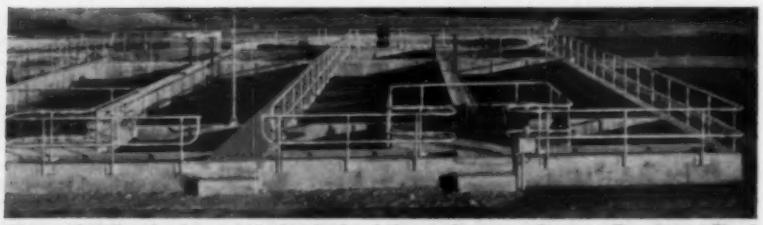

Above: Settling basins and drying beds of the modern new Sewage Treatment Plant at Clinton, Mass., showing maintenance-free aluminum railings and walkways constructed by Washington Aluminum Company.

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Economic Pipe Routes

by W. E. HOWLAND

Prof. of Civil Engineering, Purdue University, Lafayette, Ind.

WHEN STRAIGHT line structures, such as pipes, are to extend between certain fixed points on a plane surface and the cost per foot of all sections of the lines is fixed, the cost of the system of lines will be a minimum when the angles between three lines at their junction are the same as between three concurrent forces in equilibrium whose magnitudes are the corresponding unit costs of the three lines respectively. The unit costs (or costs per foot) of lines should include not only first cost but also the capitalized cost of depreciation and operation and, when pertinent, the capitalized cost of power loss in pipe and transmission lines, and the capitalized cost of vehicle operation and of lost time on highways.

This theorem can be restated, with reference to Figure 1, as follows:

Let A, B, and C be fixed points;

C_A = cost per foot of line PA, = vector along PA;

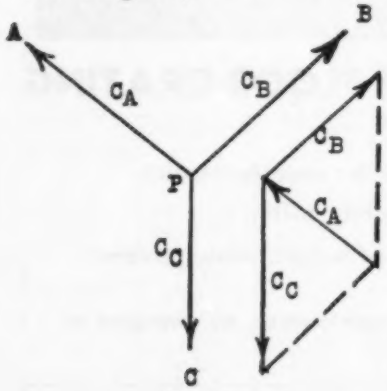


Fig. 1

C_B = cost per foot of line PB, = vector along PB; and

C_C = cost per foot of line PC, = vector along PC.

These vectors, considered as forces, will be in equilibrium when costs of lines are minimum. The position of P must be selected to meet this condition.

A purely geometrical proof is available to demonstrate this proposition.

This theorem may be generalized to apply to more than three lines intersecting at a point as follows:

When straight lines of fixed cost per foot are to radiate outward, like the spokes of a wheel, from a single point P of undetermined location to fixed points A, B, C, D, etc., on a plane surface and when the costs of each line from P—say C_A, C_B, C_C, C_D, etc.—are fixed, to obtain least cost of the sum of all lines, the point P should be so located that a group of concurrent forces directed away from P along these lines would be in equilibrium if their magnitudes were the respective unit costs C_A, C_B, C_C, C_D, etc.

A proof based on the principle of virtual work is available to prove this and all the other propositions presented in this paper.

(Note: In general, if the branching of lines is allowed the most economic system to connect P with A, B, C, D, etc. would be not straight lines radiating from P but broken lines and no more than three straight lines would join at each intersection. At each of these intersections the first proposition would apply.)

A Special Case

Suppose it is desired to find the most economical route for a branch line to leave a main route of fixed location to reach a point of fixed location. In Figure 2 the route AC is fixed. At a point P, to be determined on this route, a line is to leave and is to extend to the fixed point B. At P the cost of the main route will decrease from C_A per foot to C_C per foot, because of the take-off at P to B. The cost of line PB is C_B per foot.

For least cost, the cosine of angle CPB should be $(C_A - C_C)/C_B$. Looking at the problem from the standpoint of mechanics it appears that here only the vertical components of the analogous forces have to be in equilibrium, or as if the point P moved in a vertical frictionless groove, CA, and the horizontal component of the force directed toward B was opposed by forces from the edge of the groove. This proposition may be proved either geometrically or by the principle of virtual work.

Prior Application

A theorem for economic location of an industry with respect to its sources of raw materials and its market which utilizes the principle of the theorem here stated, appeared in "Weber's Theory of Location of Industries," an English translation* of a book by Alfred Weber.† In the Enlgish translation a proof of the theorem is not given.

The author of this article does not claim priority for his discovery. The

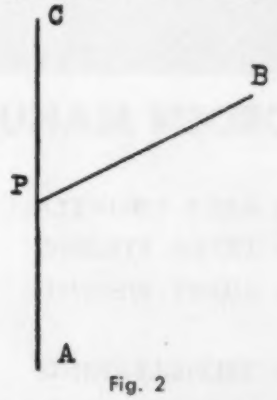
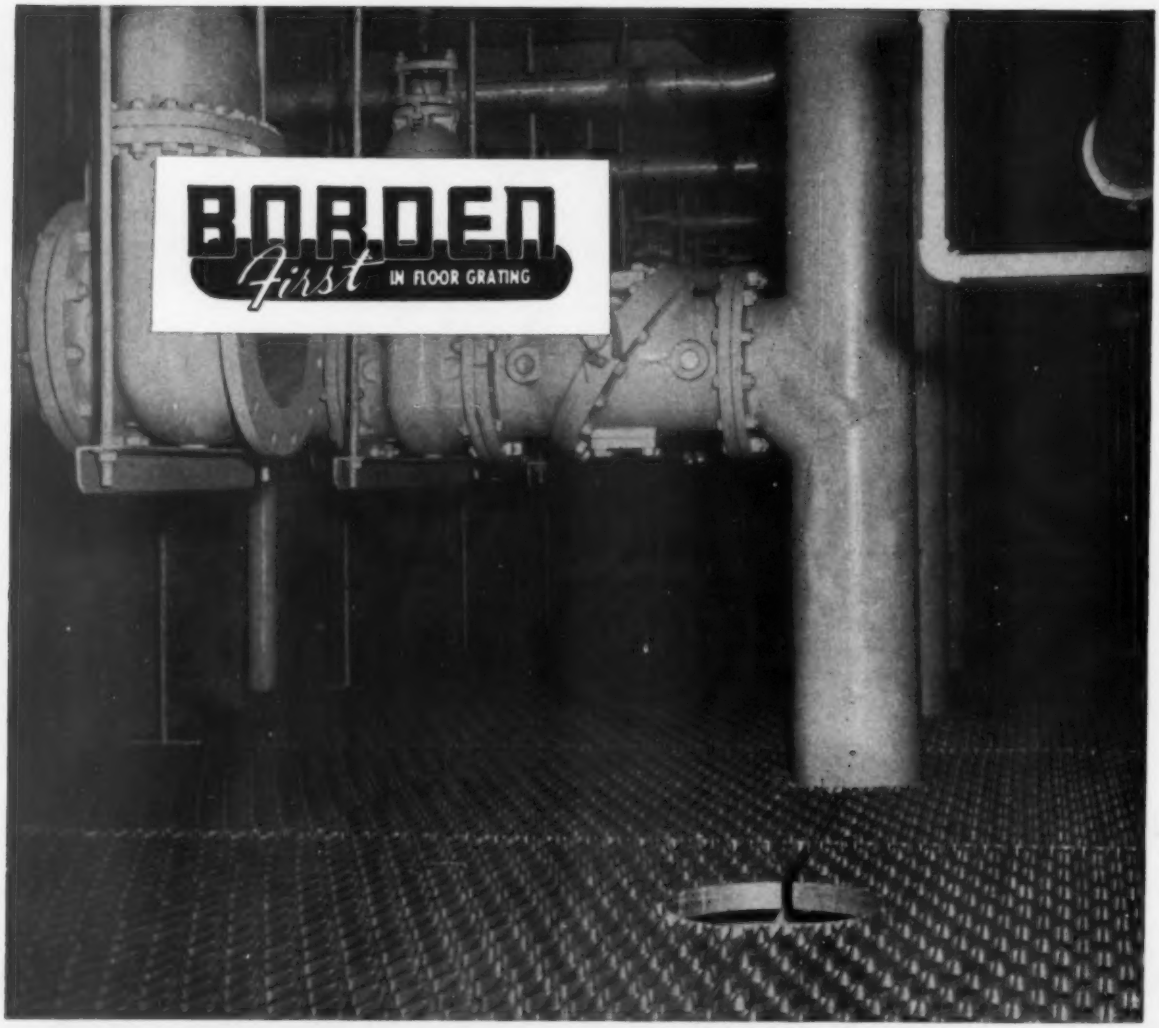


Fig. 2

article may, however, serve a useful purpose in calling attention to an important principle not widely known nor understood and little used by designers in many fields of engineering or architecture to which it is applicable.

*Edited by C. J. Friedrich, Univ. of Chicago Press (1929).

†Weber, Alfred, "Über den Standort der Industrien," Part I: "Reine Theorie des Standorts," Tubinger, Mohr (1909).



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Technical Data Section

THE DESIGN, construction and operation of water or sewage works lies in the field of sanitary engineering. This field of endeavor is quite broad; no other branch of engineering requires a knowledge of so many fundamental and applied sciences.

Source of supply for water works involves hydrology, geology, and hydraulics. Construction of facilities involves civil engineering; flow of liquid involves hydraulic principles; treatment of water and sewage involves chemical engineering unit processes in structures utilizing mechanical equipment powered by electricity. Reactions in water and sewage treatment involve inorganic, colloidal and biological chemistry.

Among the fundamentals for which a sound knowledge is essential are the subjects of chemistry and bacteriology, hydraulics, and mathematics.

Chemistry and Bacteriology

All water and sewage works laboratories should have, in their libraries, a copy of the latest edition of "Standard Methods for the Examination of Water, Sewage and Industrial Wastes", published jointly by the APHA, AWWA and the FSIWA.

The AWWA "Manual of Water Quality and Treatment" contains chapters on the chemistry and bacteriology of water treatment and several textbooks discuss the chemistry of sewage treatment. A particularly useful reprint published by *Water & Sewage Works* is "The Chemistry of Water Treatment" by Dr. A. P. Black.

Hydraulics

Measurement of flow in both water and sewage treatment systems and plants is essential to the proper operation of each. This subject has been presented in several articles in this and previous editions of the Reference & Data issue. An excellent reprint on the subject has been published by *Water & Sewage Works*, titled "Practical Hydraulics" by Prof. Robt. W. Angus.

Mathematics

No plant manager or operator can carry on his work without the use of mathematics. While higher mathematics is useful in many calculations, the simpler branches of mathematics are essential. An excellent treatise titled "Elementary Mathematics" by Prof. Warren Eglof has been published by *Water & Sewage Works*.

Charts, Nomographs and Tables

It is often helpful to an operator to have available, charts, tables, nomographs and diagrams by which mathematical calculations can be simplified. In this following section of this Reference & Data Edition, there are a number of these charts, etc. dealing with the subjects of chemistry, hydraulics and mathematics. Additional charts and nomograms, etc. will be found in previous editions of the Reference & Data Edition of *Water & Sewage Works*.

Atmospheric Pressures & Barometric Readings at Various Altitudes

Altitude Ft.	Barometric Pressure Ins. of Mercury	Atmospheric Pressure Lbs. per sq.in.	Equivalent head of water in ft.	Boiling Point of Water°F.	Altitude Ft.	Barometric Pressure Ins. of Mercury	Atmospheric Pressure Lbs. per sq.in.	Equivalent head of water in ft.	Boiling Point of Water°F.
0	29.92	10.7	34.0	212.0	5000	24.89	12.2	28.2	202.9
500	29.38	14.4	33.3	211.1	5500	24.43	12.0	27.8	201.9
1000	28.86	14.2	32.8	210.2	6000	23.98	11.8	27.3	201.0
1500	28.33	13.9	32.2	209.3	6500	23.53	11.5	26.6	200.1
2000	27.82	13.7	31.7	208.4	7000	23.09	11.3	26.2	199.2
2500	27.31	13.4	31.0	207.4	7500	22.65	11.1	25.7	198.3
3000	26.81	13.2	30.5	206.5	8000	22.22	10.9	25.2	197.4
3500	26.32	12.9	29.8	205.6	8500	21.80	10.7	24.8	196.5
4000	25.84	12.7	29.4	204.7	9000	21.38	10.5	24.3	195.5
4500	25.36	12.4	28.7	203.8	10000	20.58	10.1	23.4	193.7

Alkalinity Measurements in Water

by G. DONG, R. L. GIUSTI, and A. E. GREENBERG

Division of Laboratories of the California State Department of Public Health

THE 10TH EDITION of *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes*[1] introduced a new concept into the procedure for the determination of alkalinity in water. This concept is that the equivalence point in the titration varies with the total alkalinity and that, therefore, different equivalence points must be selected for the titration of waters of different alkalinities. According to *Standard Methods* the following pH values should be used as the equivalence points for the corresponding total alkalinities as calcium carbonate: pH 5.1 for total alkalinities of about 30 mg/l, pH 4.8 for 150 mg/l, and pH 4.5 for 500 mg/l.

Although the term equivalence point and its method of calculation are well known to chemists, the plant operator who makes alkalinity titrations may be confused by this new complication in *Standard Methods*. It is the purpose of this paper to present, in as simple a form as possible, a discussion of alkalinity and its measurement.

Definitions

Alkalinity is a measure of the quantity of basic compounds present. It is measured by titration with an acid of known strength. Alkalinity in water is due principally to carbonates, bicarbonates, and hydroxides. Borates, phosphates, and silicates also contribute to the total alkalinity; since their concentration is usually small, especially by comparison with the carbonates and bicarbonates, they are customarily neglected in calculations.

The pH of a solution is a measure of the intensity of acidity or alkalinity. pH is measured on an arbitrary scale from 0 to 14. It should not be confused with alkalinity which is a measure of quantity.

The equivalence point is that point in a titration at which an amount of a standard solution exactly equivalent to the substance sought has been added. This is also known as the theoretical end point. In an alkalinity determination the equivalence point corresponds to that pH at which the quantity of added acid is exactly equal to the quantity of alkalinity present in the sample.

The end point of a titration is that point at which an abrupt observable change occurs. Ideally this is at the equivalence point. In an alkalinity titration using indicators, the color change does not necessarily occur at the theoretical end point. This may lead to an appreciable error in the titration. When using a pH meter, however, an abrupt change in pH is observed at the theoretical end point.

Theoretical Discussion

When sulfuric acid is gradually added to a solution of sodium carbonate, two reactions take place: First, all of the carbonate is converted to bicarbonate:

$$2Na^+ + 2CO_3^= + 2H^+ + SO_4^= \rightleftarrows 2Na^+ + 2HCO_3^- + SO_4^= \quad (1)$$

Second, after all of the carbonate has been converted, the resulting bicarbonate is converted in turn to carbonic acid:

$$2Na^+ + 2HCO_3^- + 2H^+ + SO_4^= \rightleftarrows 2Na^+ + 2H_2CO_3 + SO_4^= \quad (2)$$

Plotting the results of such a titration of sodium carbonate, using milliliters of standard acid as the abscissa and pH as the ordinate, the curve shown in Fig. 1 is obtained. This curve is typical of a carbonate system in that it shows two equivalence points. Point B is the bicarbonate equivalence point; that is, the pH at which all of the carbonate has been converted to bicarbonate (Equation (1) above). This occurs at pH 8.3. Point C is the equivalence point for carbonic acid; that is, the pH at which all of the bicarbonate has been converted to carbonic acid (Equation (2) above). In the determination of alkalinity in water, Point C is of prime importance because it indicates complete neutralization of the bases present.

The pH at these end points can be calculated for any given set of conditions. Since the titration involves two equivalence points, there are two ionization equilibria to be considered:

$$CO_3^= + H^+ \rightleftarrows HCO_3^- \quad (3)$$

and

$$HCO_3^- + H^+ \rightleftarrows H_2CO_3 \quad (4)$$

The ionization constant for reaction (3), K_2, is expressed as

$$K_2 = \frac{[H^+]\ [CO_3^=]}{[HCO_3^-]}. \quad (5)$$

Solving for $[H^+]$ yields

$$[H^+] = K_2 \frac{[HCO_3^-]}{[CO_3^=]}. \quad (6)$$

Converting to logs of the reciprocals we have

$$\log \frac{1}{[H^+]} = \log \frac{1}{K_2} - \log \frac{[HCO_3^-]}{[CO_3^=]}. \quad (7)$$

Since $\log \frac{1}{[H^+]}$ equals, by definition, pH, equation (7) may be rewritten

$$pH = \log \frac{1}{K_2} - \log \frac{[HCO_3^-]}{[CO_3^=]}. \quad (8)$$

K_2, the ionization constant is known. It equals 4.7×10^{-11}. Substituting, we find

$$pH = \log \frac{1}{[4.7 \times 10^{-11}]} - \log \frac{[HCO_3^-]}{[CO_3^=]}, \quad (9)$$

or

$$pH = 10.2 - \log \frac{[HCO_3^-]}{[CO_3^=]}. \quad (10)$$

In the same way, equation (4) is solved. K_1, the ionization constant, is

$$K_1 = \frac{[H^+]\ [HCO_3^-]}{[H_2CO_3]}, \quad (11)$$

and

$$pH = \log \frac{1}{K_1} - \log \frac{[H_2CO_3]}{[HCO_3^-]}. \quad (12)$$

Since $K_1 = 4.3 \times 10^{-7}$, then

$$pH = 6.4 - \log \frac{[H_2CO_3]}{[HCO_3^-]}. \quad (13)$$

Using equations (10) and (13), the equivalence points for a series of titrations of solutions of different alkalinities were calculated. These are shown in Table 1. It is clear from this table that the bicarbonate equivalence point occurs consistently at a pH of 8.3 ± 0.1. However, it can also be seen that the carbonic acid equivalence point varies rather widely and decreases with increasing alkalinity. Thus, the recommendations of *Standard Methods* are entirely consistent with theory.

Practical Considerations

In the analysis of unknown samples it is obviously impossible to know the total alkalinity or the correct equivalence point to use in measuring the total alkalinity. This diffi-

culty may be eliminated in several ways: (1) Titrate the sample to any arbitrary pH end point around 5 to establish the order of magnitude of total alkalinity. Use this approximation to select the correct equivalence point and complete the titration, or (2) select a pH for routine use on all samples which will provide a minimum error in the total alkalinity.

TABLE 1

Equivalence Points Calculated for Different Alkalinities*

Alkalinity mg/l as $CaCO_3$	Equivalence Point Carbonate-Bicarbonate	Carbonate-Carbonic Acid
30	8.2	5.1
60	8.2	5.0
150	8.3	4.8
200	8.3	4.7
500	8.3	4.6
1,000	8.3	4.5

*Na_2CO_3 solutions titrated with 0.02N H_2SO_4

The 9th and earlier editions of *Standard Methods* used the second alternative. By specifying methyl orange as the indicator the end point was taken at about pH 4.3. The errors resulting from the use of pH 4.3 as the end point in the determination of total alkalinity may be considerable. They are shown in Table 2. Note that at low alkalinities the error is large, but that it decreases as the alkalinity increases. For good reason, then, the 10th edition of *Standard Methods* has changed the recommended procedure.

The first alternative given above is, however, not a universally acceptable one since it involves additional complications which may thoroughly discourage the plant operator. Our laboratory has simplified this by using a single pH value as the end point for all alkalinity titrations; by carefully selecting this value, we have minimized the errors. The pH of choice is 4.8. In Table 3 are shown the errors which are much smaller than those obtained with a pH of 4.3.

It is true that the selection of pH 4.8 as suggested here, or the sliding pH values given by Standard Methods, means that methyl orange can not be used as the indicator. However, inspection of Table 2 shows that the error in total alkalinity, when using methyl orange as indicator, is 5 mg/1, or very close to it. Therefore, those who are familiar with methyl orange and wish to continue its use may simply subtract 5 mg/1 from the methyl orange alkalinity and be within one percent of the actual value. Methyl orange is, unfortunately, a notoriously difficult indicator to use. The mixed brom cresol green-methyl red indicator given in *Standard Methods,* or, better yet, the methyl purple indicator suggested by Fleisher[2] and Frey[3] would be preferable. This indicator has a very sharp color transition from green to purple at pH 4.8. Ideally, a pH meter can be used.

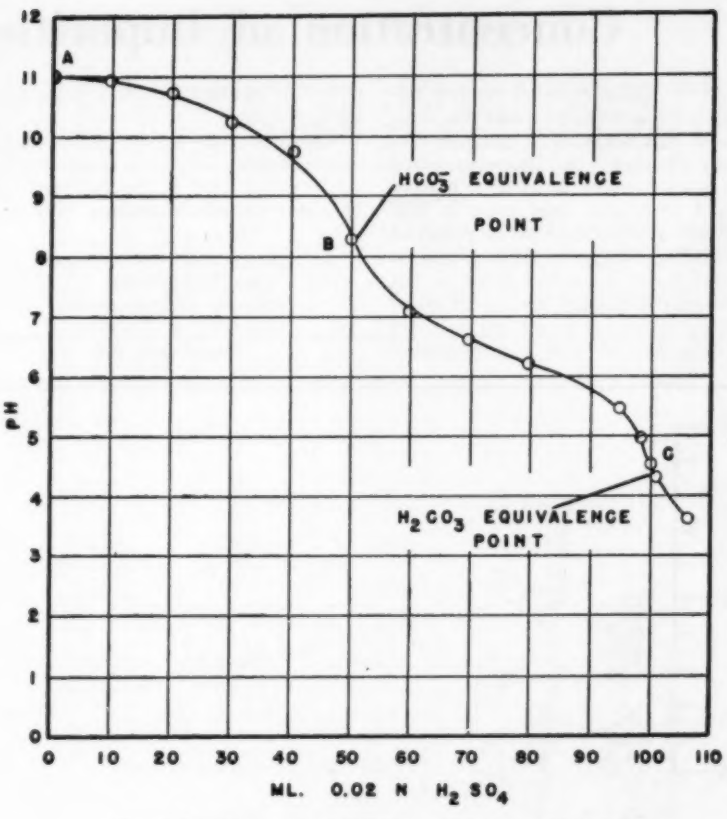


Fig. 1. Titration curve of 1,000 mg/L Na_2CO_3 with H_2SO_4

Summary and Conclusions

The relationship between the total alkalinity and the equivalence point in the titration of total alkalinity has been verified.

To eliminate the sliding scale of pH end points for samples of different alkalinities, it is suggested that pH 4.8 be taken as the end point in all titrations. This pH can be accurately measured by means of methyl purple indicator or a pH meter.

TABLE 2

Deviations in Total Alkalinity Using pH 4.3 as End Point

Total alkalinity at theoretical equivalence point mg/l	Total observed alkalinity using pH 4.3 as end point mg/l	Deviation %
30	35	+16.7
60	65	+ 8.3
150	156	+ 4.0
200	206	+ 3.5
500	505	+ 1.0
1,000	1,005	+ 0.5

TABLE 3

Deviations in Total Alkalinity Using pH 4.8 as End Point

Total alkalinity at theoretical equivalence point mg/l	Total observed alkalinity using pH 4.8 as end point mg/l	Deviation %
30	31.5	+5.0
60	62	+3.3
150	150	0.0
200	197	−1.5
500	495	−1.0
1,000	990	−1.0

References

(1) Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 10th ed. A.P.H.A., New York (1955).

(2) Fleisher, H., "Sensitive Indicator for Volumetric Determination of Boiler Feedwater Alkalinity." Ind. Eng. Chem., Anal. Ed., Vol. 15, 12, 742-743 (1943).

(3) Frey, R. W. "Methyl Purple vs. Methyl Orange in Alkalinity Titrations." Water and Sewage Works, Vol. 100, 6228 (1953).

Concentration of Impurities in Water

A nomograph

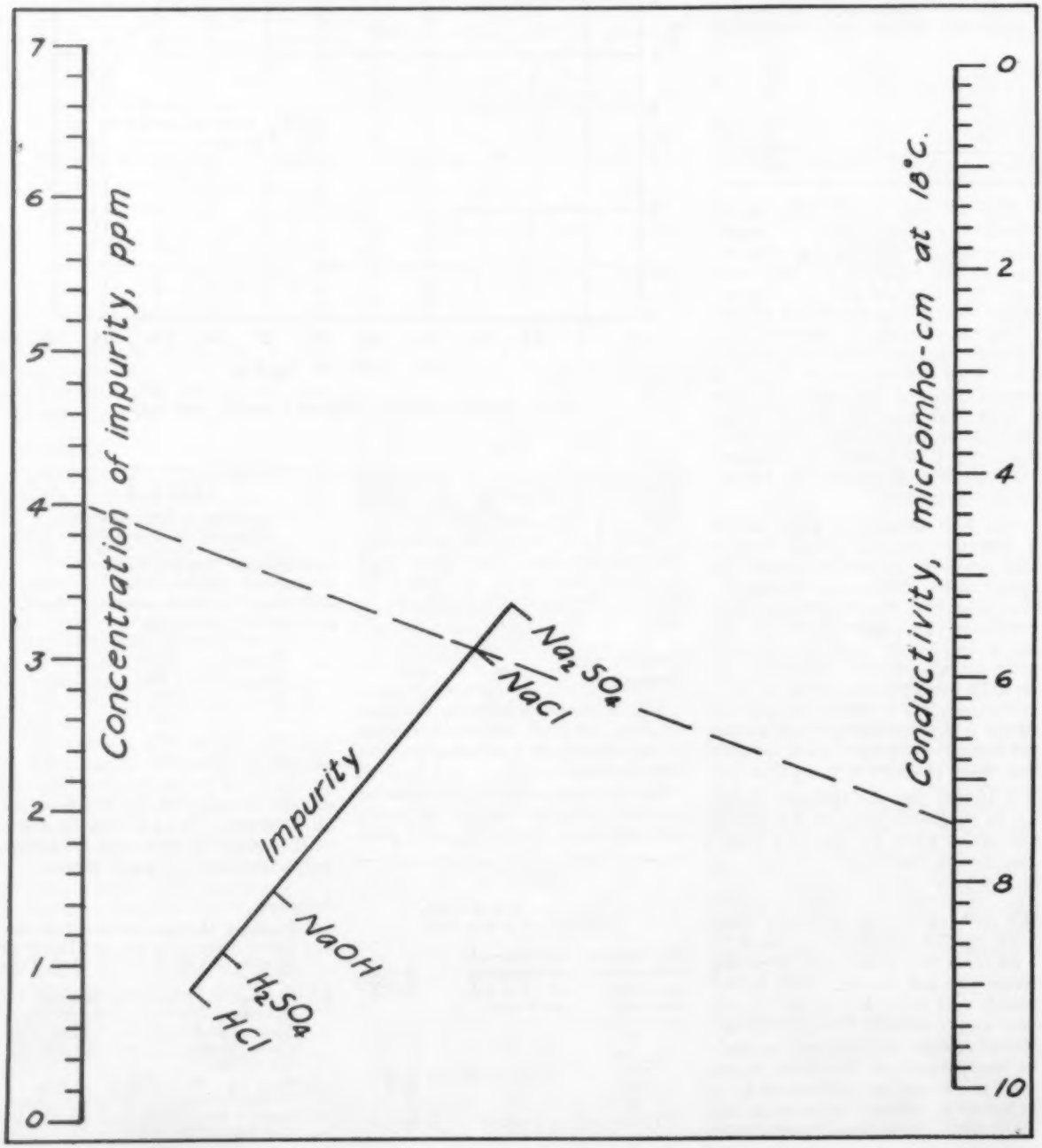
by D. S. DAVIS
Professor of Engineering
University of Alabama
Tuscaloosa, Ala.

MANY PROCESSES require deionized or distilled water that contains a maximum of 5 ppm of dissolved electrolyte. However, such high purity water is more corrosive toward iron and steel than is less pure water, especially in the presence of dissolved oxygen. Concentrations of electrolytic impurities in water can be estimated through use of the nomograph, which is based on a chart given by Friend[2] that was calculated from ion conductance data presented by Glasstone[3].

The index line on the chart, which was constructed by well-known methods[1], shows that if the conductivity of water known to contain only sodium chloride is 7.4 micromho-cm at 18° C., the concentration of that impurity is 4 ppm.

References

(1) Davis, D. S., 'Nomography and Empirical Equations,' Chap. 10, New York, Reinhold Publishing Corporation, 1955.
(2) Friend, W. Z., Corrosion, 13 (1) 97 (1957).
(3) Glasstone, Samuel, 'Textbook of Physical Chemistry,' page 880, New York, D. Van Nostrand Company, Inc.



Solubility of Oxygen in Water

FOR THE SOLUBILITY of atmospheric oxygen in water at temperatures between 0° and 35° C, Hatfield[2] gives the equation

$$S = \frac{0.678\ (P-\mu)}{t + 35}$$

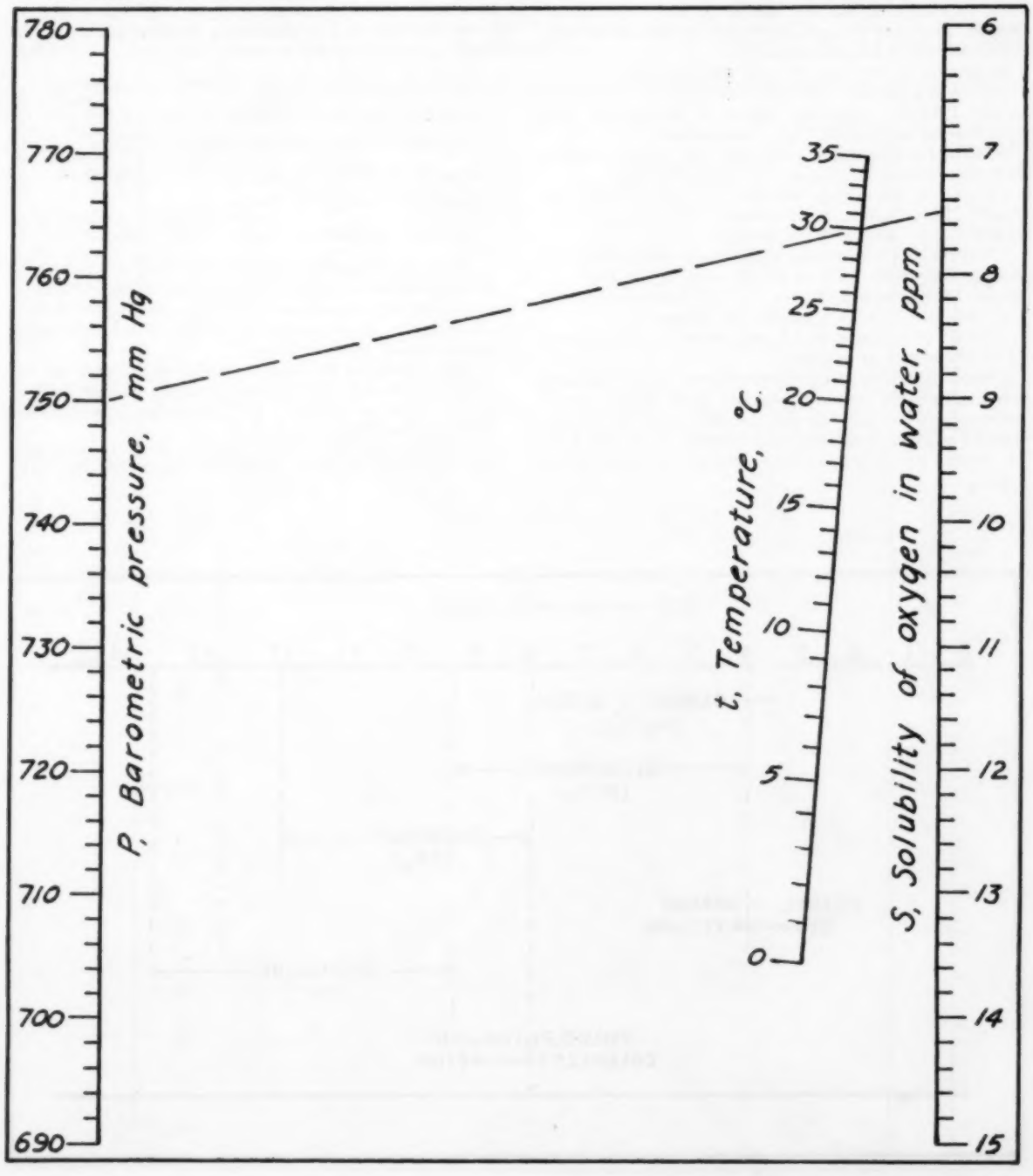
where

S = solubility of oxygen in ppm
P = barometric press. in mm of mercury
μ = vapor pressure of water at t° C.

The nomograph, constructed through recourse to line coordinate methods[1], enables rapid and accurate solution of the equation. The use of the chart is illustrated as follows: What is the solubility of oxygen in water at 30° C, in equilibrium with air, when the barometric pressure is 750 mm of mercury? Connect 750 on the P-scale and 30 on the t-scale with a straight line. Note the intersection with the S-scale at solubility of 7.5 ppm of oxygen.

A nomograph

by D. S. DAVIS
Professor of Engineering
University of Alabama
Tuscaloosa, Ala.



References

(1) Davis, D. S., "Nomography and Empirical Equations," Chap. 10, Reinhold Publishing Corporation, 1955.

(2) Hatfield, W. D., Sewage Works Journal, p. 557, May, 1941.

pH—Alkalinity

Relationships in Natural and Treated Waters, and in Laboratory Titrations

THE accompanying chart reveals the various types of alkalinity present in water at different parts of the pH scale. It will also help the laboratory man or the plant operator to better understand the reactions involved when titrating samples for alkalinity and free carbon-dioxide. The color change points for the indicators commonly employed are indicated.

Inspection of the chart reveals the following:

(1) When the pH is between 4.0 and 8.0 only bicarbonate (HCO_3) alkalinity alone, a bicarbonate with some free carbondioxide (CO_2) are present.

(Any carbonate would react with the carbonic acid to form bicarbonate $(CO_3) + H_2CO_3 = 2HCO_3$)

(2) When the pH is between 8.0 and 9.4 only carbonate (CO_3) alone, or bicarbonate (HCO_3) and carbonate (CO_3) alkalinity are present.

(Any hydroxyl alkalinity would react with bicarbonate to form carbonate $(OH + HCO_3 = CO_3 + H_2O)$

(3) When the pH is over 9.4 only hydroxide (OH) and carbonate (CO_3) alkalinity are present.

(4) At pH values of 12 and above only hydroxide (OH) alkalinity is present.

[ED. NOTE—*The chart in one respect may prove somewhat misleading, namely, the pH zone shown for bicarbonate which extends past pH 8.0 to pH 9.4. Bicarbonates alone will not give values in excess of pH 8. To go beyond pH 8 requires the presence of some normal carbonate and the zone indicated includes some carbonate in addition to bicarbonate. The same consideration must be given the indicated zone for carbonic acid, or free CO_2. At values above pH 4 there must be present some bicarbonate alkalinity along with the carbonic acid.*]

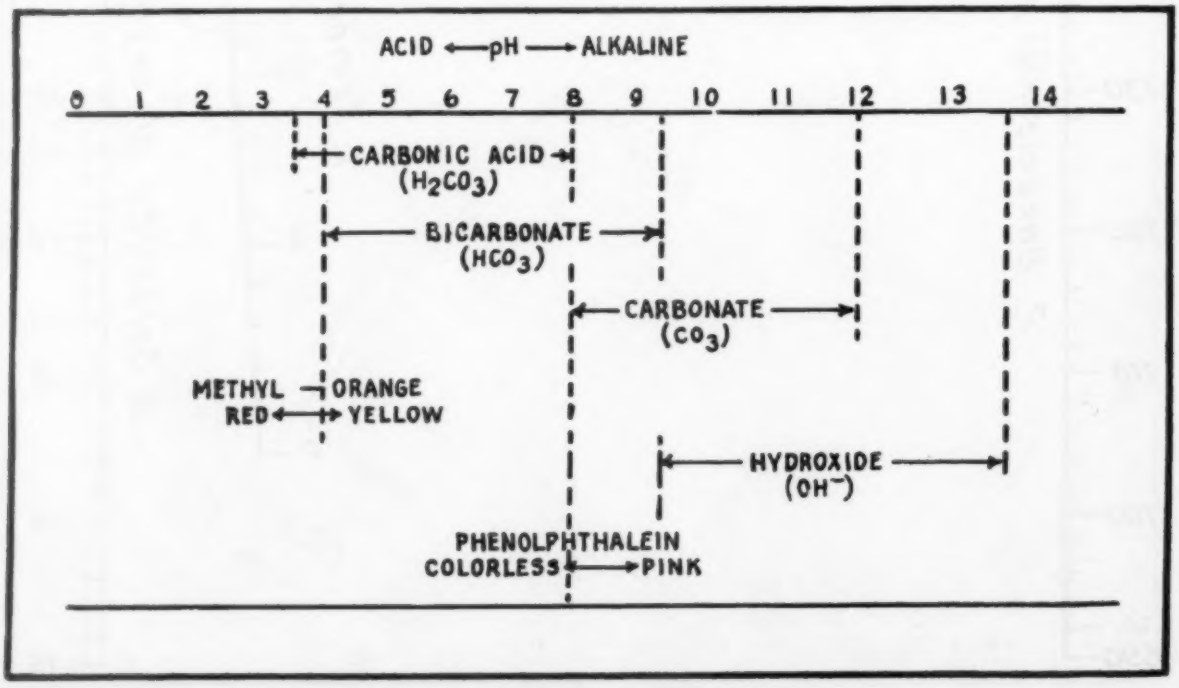
As standard acid is added to a water of high pH, the following reactions will occur:

1. Hydroxide + Acid	= Neutral Salt, only	Complete at pH 8.0
$2NaOH + H_2SO_4$	$= Na_2SO_4 + H_2O$	
2. Carbonate + Acid	= Bicarbonate + Neutral Salt	Complete at pH 8.0
$2Na_2CO_3 + H_2SO_4$	$= 2NaHCO_3 + Na_2SO_4$	
3. Bicarbonate + Acid	= Neutral Salt + Carbon Dioxide	Complete at pH 4.0
$2NaHCO_3 + H_2SO_4$	$= Na_2SO_4 + H_2O + CO_2$	

From these equations it is evident that at a pH of 8.0 the acid will have reacted with all of the hydroxyl alkalinity and ½ of the carbonate alkalinity. At a pH of 4.0 the remaining ½ of the carbonate and all of the bicarbonate alkalinity will be neutralized.

Some study of the last statement will enable an operator to calculate the type of alkalinity present without having to refer to the "PT" formulas in "Standard Methods for Water Analysis."

[*The above was taken from a paper by D. W. Graham, Chief Chemist, Bureau of Water Works and Supply, Los Angeles.*]



Shock Pressure from Water Hammer

A Nomograph
by D. S. DAVIS
Professor of Engineering
University of Alabama
Tuscaloosa, Ala.

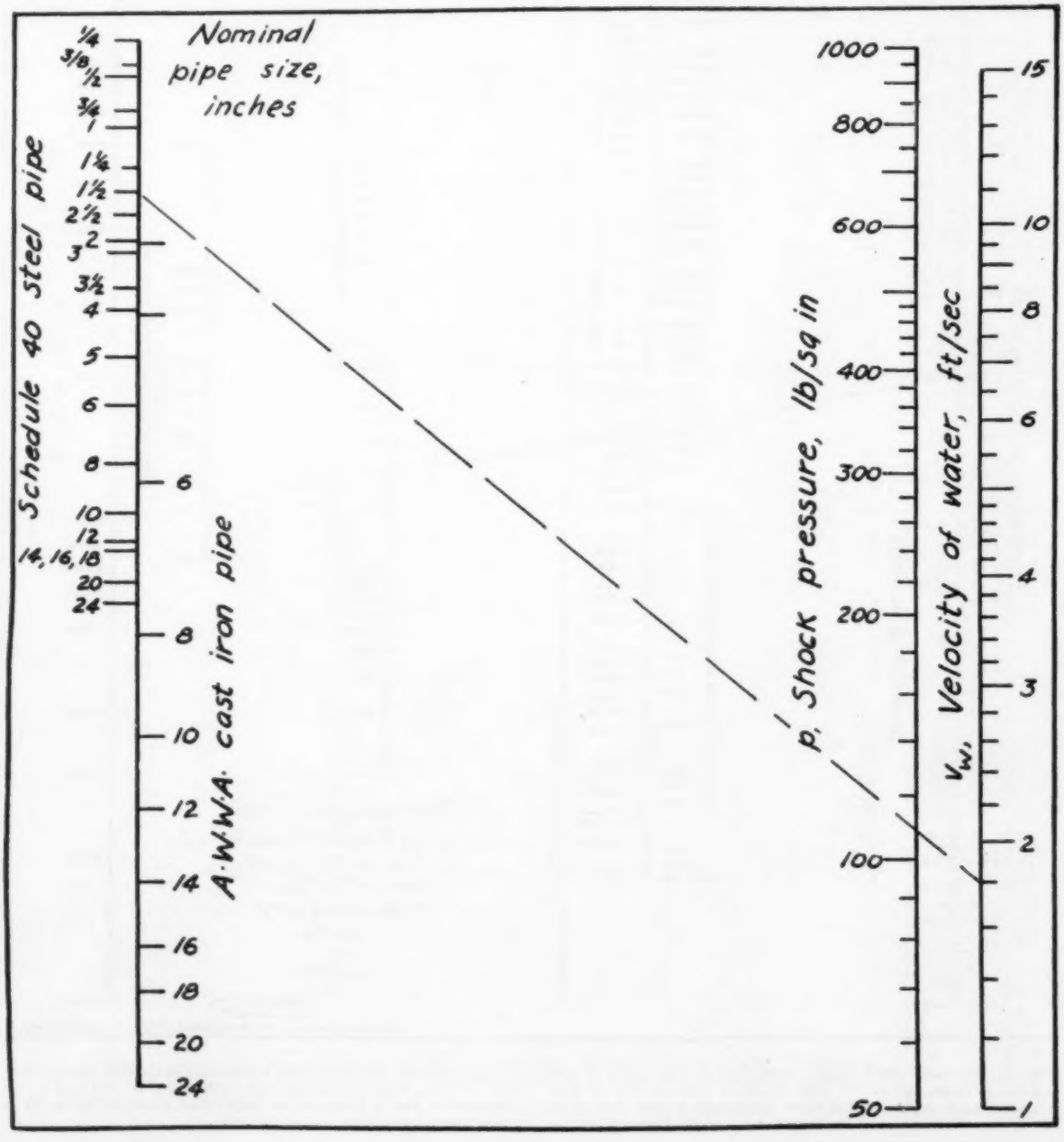
DATA[1] that deal with V_p, velocity of pressure wave in feet per second; V_w, velocity of water in feet per second; and p shock pressure in pounds per square inch for instantaneous closure of valves in water lines can be correlated by means of the expression.

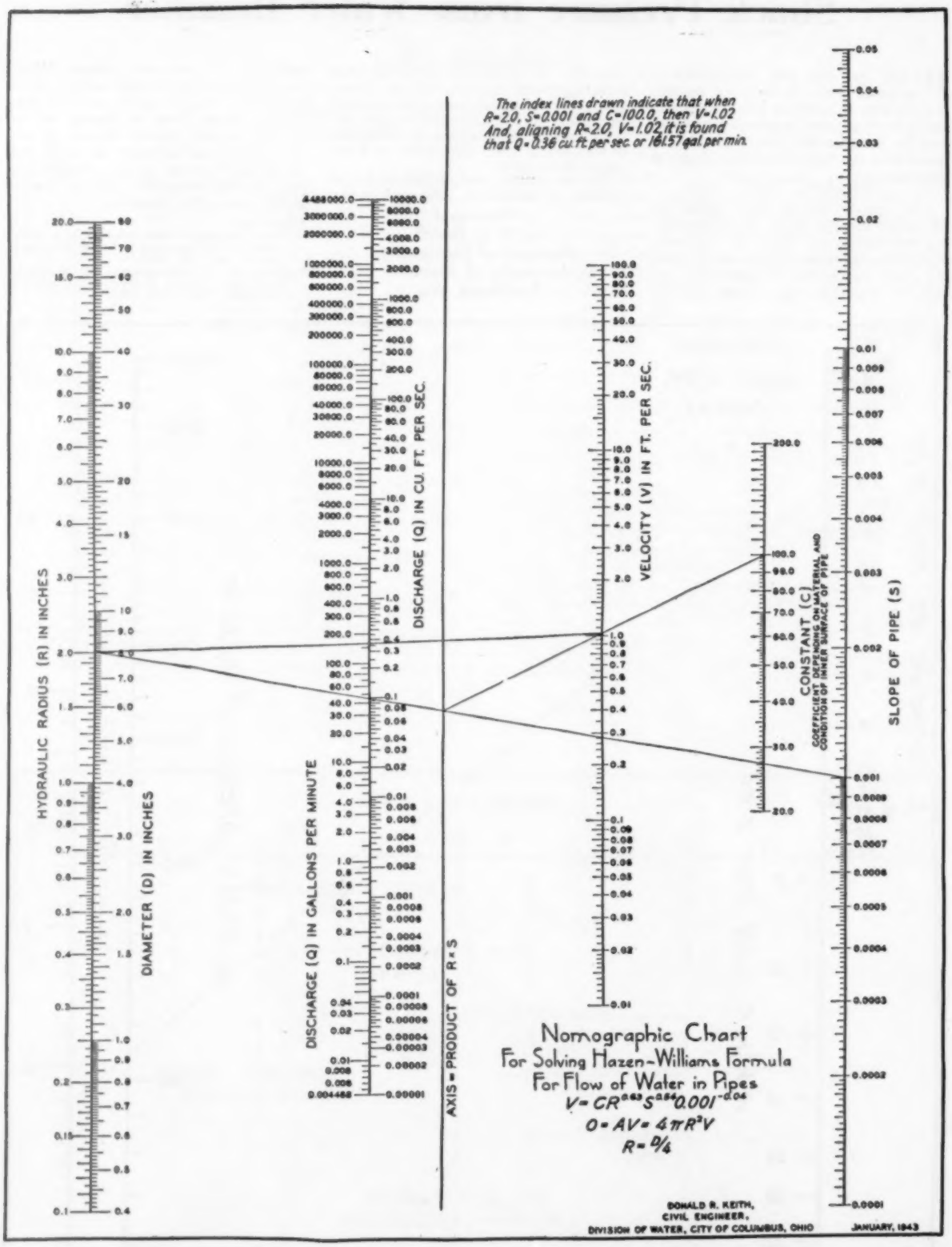
$$p = 0.01369\ Vw\ (Vp - 76.6)$$

This equation can be solved readily and accurately through use of the accompanying nomograph on which V_p has been replaced by the nominal pipe size in inches for both Schedule 40 steel pipe and AWWA cast iron pipe. (Note that for steel pipe, the graduation for 2-inch pipe appears between that for 2½ and 2-inch pipe. This situation does not represent an error; the scaling depends upon the ratio of internal diameter to thickness of wall and is exact agreement with accepted dimensions.

The use of the chart, which was constructed in accordance with well-known methods[2], is illustrated as follows: What shock pressure should result when a valve is suddenly closed in a 1½ inch steel pipe through which water is flowing at 1.8 feet per second? Connect 1½ on the left side of the nominal pipe size scale and 1.8 on the V_w-scale with a straight line and note the intersection with the p-scale at 110 pounds per square inch.

References
1. Crane Company, Valve World, No. 3, 1951, reproduced in Paper and Pulp Mill Catalogue, 33rd ed., page 543, 1956-57.
2. Davis, D. S., "Nomography and Empirical Equations," Chapter 6, New York, Reinhold Publishing Corporation, 1955.



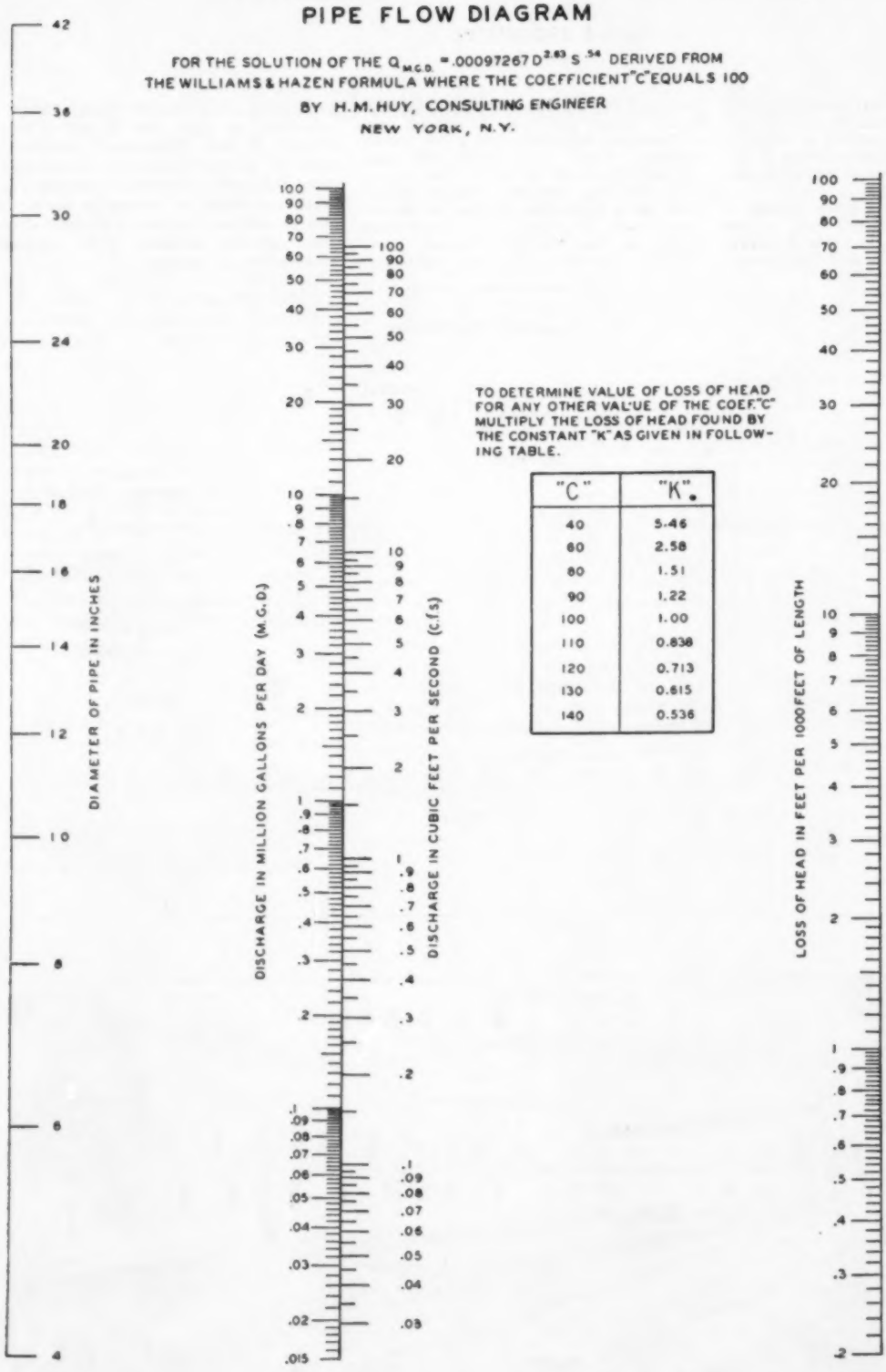

The index lines drawn indicate that when R=2.0, S=0.001 and C=100.0, then V=1.02
And, aligning R=2.0, V=1.02 it is found that Q=0.36 cu. ft. per sec. or 161.57 gal per min.
HYDRAULIC RADIUS (R) IN INCHES
DIAMETER (D) IN INCHES
DISCHARGE (Q) IN GALLONS PER MINUTE
DISCHARGE (Q) IN CU. FT. PER SEC.
AXIS = PRODUCT OF R × S
VELOCITY (V) IN FT. PER SEC.
CONSTANT (C)
COEFFICIENT DEPENDING ON MATERIAL AND CONDITION OF INNER SURFACE OF PIPE
SLOPE OF PIPE (S)
Nomographic Chart
For Solving Hazen-Williams Formula
For Flow of Water in Pipes
$V = CR^{0.63}S^{0.54}0.001^{-0.04}$
$Q = AV = 4\pi R^2 V$
$R = D/4$
DONALD R. KEITH,
CIVIL ENGINEER,
DIVISION OF WATER, CITY OF COLUMBUS, OHIO
JANUARY, 1943

Directions for using chart: Place straightedge on "D" scale at pipe diameter in inches and on "S" scale at loss of head per foot of pipe. Determine point on "Axis" line where straightedge crosses. Then place straightedge on this point on the Axis line and at Constant "C" for the pipe in question. Determine point where straightedge then crosses Velocity "V" scale. Next place straightedge on this point on "V" scale and on diameter of pipe in inches on "D" scale. Read Discharge "Q" in cfs or gpm where straightedge crosses "Q" line.

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267 D^{2.63} S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H.M. HUY, CONSULTING ENGINEER
NEW YORK, N.Y.


DIAMETER OF PIPE IN INCHES
DISCHARGE IN MILLION GALLONS PER DAY (M.G.D.)
DISCHARGE IN CUBIC FEET PER SECOND (c.f.s.)
LOSS OF HEAD IN FEET PER 1000 FEET OF LENGTH

TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

(b) FRICTION COEFFICIENT "C": Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at 100. This figure, divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

Directions for Application of This Diagram

(a) FRICTION-HEAD LOSS: A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient, due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"], multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.)

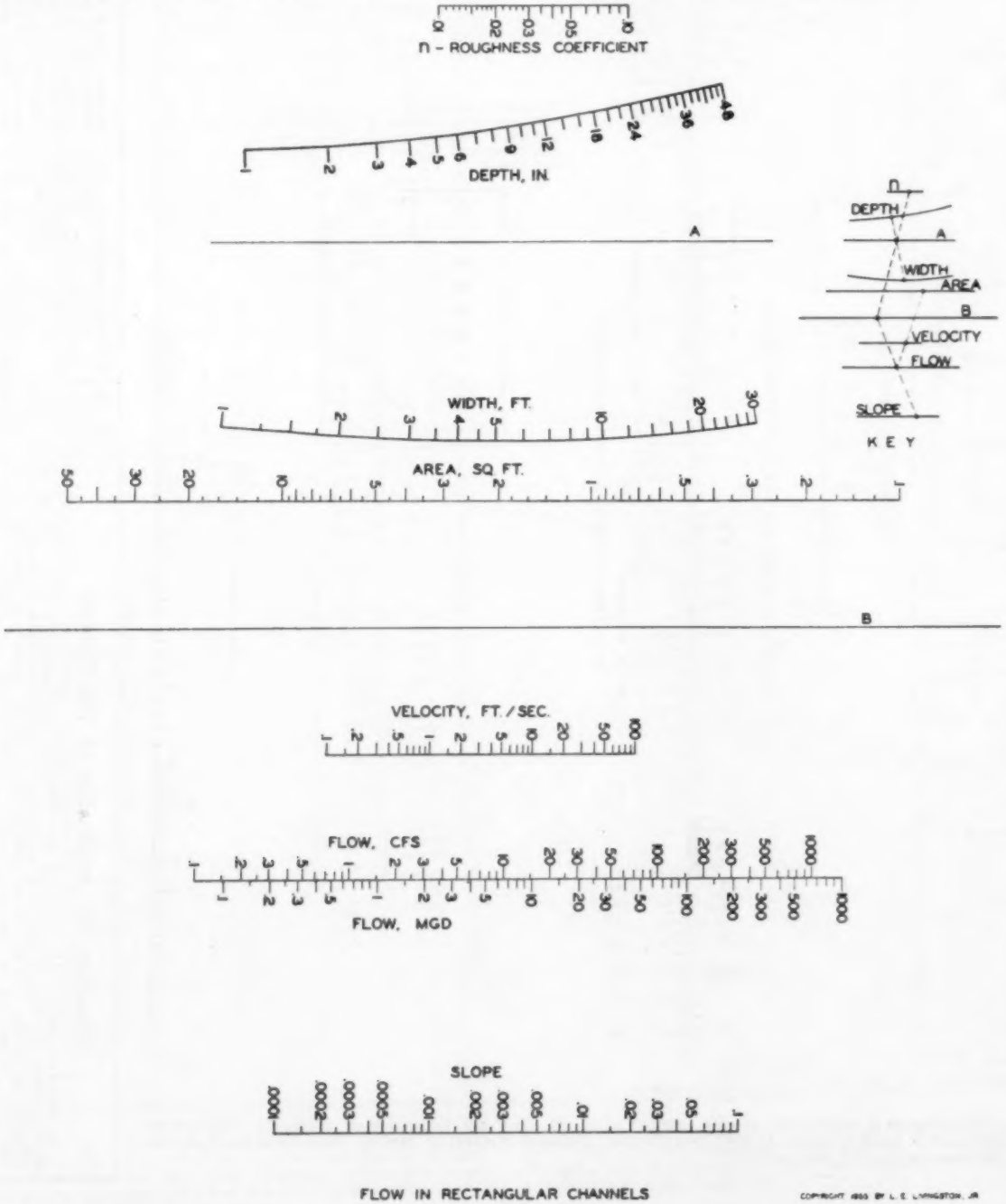
Flow in Rectangular Channels

by L. E. LIVINGSTON, Jr.
Dallas, Texas

The accompanying chart provides a convenient solution to Manning's formula for open channel flow, as applied to rectangular channels. A complete solution is accomplished in four steps as shown in the key.

To find the flow in a given channel, a line is drawn through the "Depth" of flow and "Width" lines to pivot line A. Draw a second line through A and "Roughness" to pivot line B, and third line through B and "Slope" to "Flow." If desired, area is calculated separately, and a line drawn through "Area" and "Flow" will pass through "Velocity" at the correct figure.

To find the required channel dimensions for a given flow, proceed in the reverse order. If velocity is a controlling factor, a line through "Velocity" and "Flow" determines the area necessary. Then draw a line through "Flow" "Slope" (assumed) to pivot line B, and a line through B and "Roughness" locates a point on A. By rotating a straightedge about this point, a suitable combination of depth and width of channel is found. It may be necessary to select a different slope and repeat the calculation if the required area cannot be obtained.



FLOW IN RECTANGULAR CHANNELS

COPYRIGHT 1955 BY L. E. LIVINGSTON, JR.

The Hydraulic Pumping Ram*

THE increased development of certain rural areas for farming and other purposes has introduced many urgent problems of water supply for which effective and economical solutions have been found in the use of the Hydraulic Pumping Ram, a machine which can be manufactured quickly and installed with the minimum of constructional work.

The hydraulic ram will work efficiently on any fall of water of 3 feet or more, up to about 80 feet, and will elevate water up to 300 feet. For the highest delivery heads however, a working fall of at least 12 feet is necessary. The following expression is useful :—

$$q = \frac{QH}{h}\eta$$

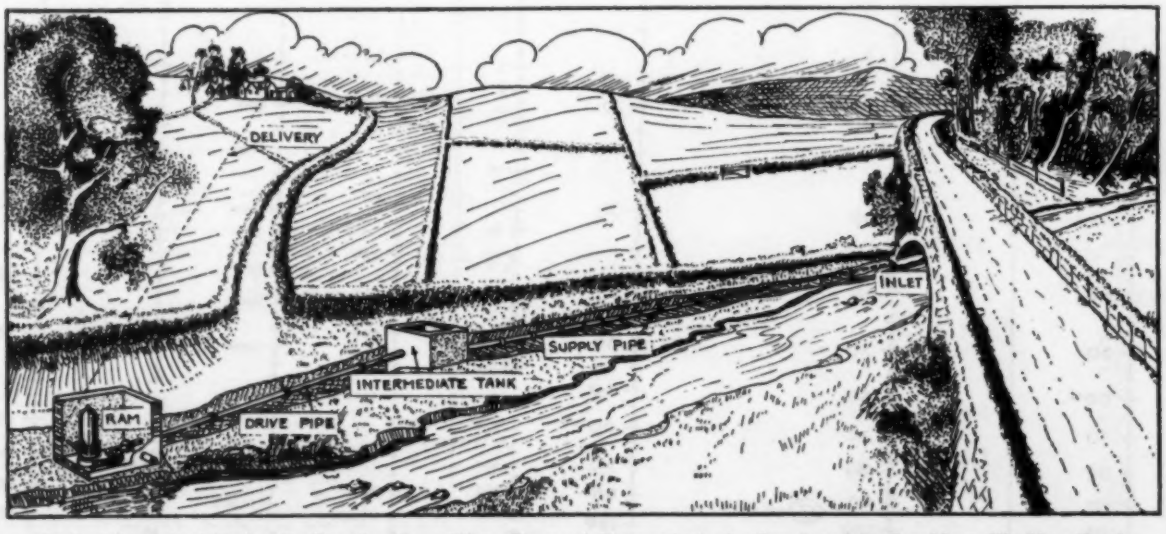
Where q = water raised, g.p.m.
h = height water is raised above ram, feet.
Q = flow of water used by ram, g.p.m.
H = working fall, feet.
η = efficiency. (Average value for rough calculations 0.6).

Efficiency varies with the different factors, particularly with the ratio of the length of the drive pipe to the working fall H, and falls off if ratio of delivery to supply head becomes very great. It is recommended that the ratio of the length of the drive pipe to the working fall be made not much more than 6, with a mimimum length of drive pipe of about 60 feet. But there is no hard and fast rule about this, and many rams are working satisfactorily with ratios much greater than 6 and with drive pipes much shorter than 60 feet.

The working head can be obtained in various ways. If a water fall exists in a stream, or if two water sources are available at different levels, an inlet can be made at the high level and a drive pipe of suitable length laid directly to the ram situated at the low level. If, on the other hand, the hydraulic gradient of a stream is to be utilized, a fall can be developed in the manner shown in the sketch above, in which a feed pipe is taken from an inlet to an intermediate chamber built up to the same level as the inlet, and from this chamber a drive pipe laid to the ram. It is very desirable in all cases that the drive pipe, which must be of flanged cast-iron or screwed steel piping, be laid in a straight line with uniform gradient. The supply pipe to the intermediate chamber and the rising main can be laid to follow the contours of the ground, although peaks should be avoided, as there is risk of air collecting and impeding flow. If a peak cannot be avoided an air valve should be fitted at the highest point. No peak may rise above the hydraulic gradient.

The hydraulic ram can be "simple" or "compound." The "simple" ram lifts part of the water used to drive it, the "compound" machine is operated by one source, as from a stream, and lifts water from another source, as from a spring. Direct contamination of the spring water by the stream water is avoided.

*From the *Glenfield Gazette*—A Journal of Hydraulic Engineering; Glenfield and Kennedy, Ltd., Kilmarnock, Scotland.



Typical Layout of Hydraulic Pumping Ram, When Slope of Stream is to be Developed to Provide a Working Head

Contents of Rectangular Tanks

Cubic Feet, Gallons, Pounds, and Tons of Water

THIS chart will be found useful for rectangular tank determinations. The dimensions of the tank, all in inches, are given in columns A, C, and D. Then, as will be noted, you can find the number of cubic feet in column E, the gallons in column F, the pounds of water in column G, and the tons of water in column H. As a typical example, let us say that the width of a given tank is 10 inches, the depth 5 inches, and the length 20 inches. How many pounds of water will the tank hold?

How to Use the Chart

Find the 10 in column A and run a straight line over to the 5 in column C and locate the intersection with column B. Then from that point of intersection run over to the 20 in column D, and note the intersection with column C. It will be observed now that column C and J are exactly alike so that perfectly horizontal lines can be drawn between those two columns. In this instance the intersection in column C happens to be through the 10, so simply run a straight line through the 10 in column C and the 10 in column J, as shown by the dotted line, and you have a perfectly horizontal line which gives all of the answers as follows:

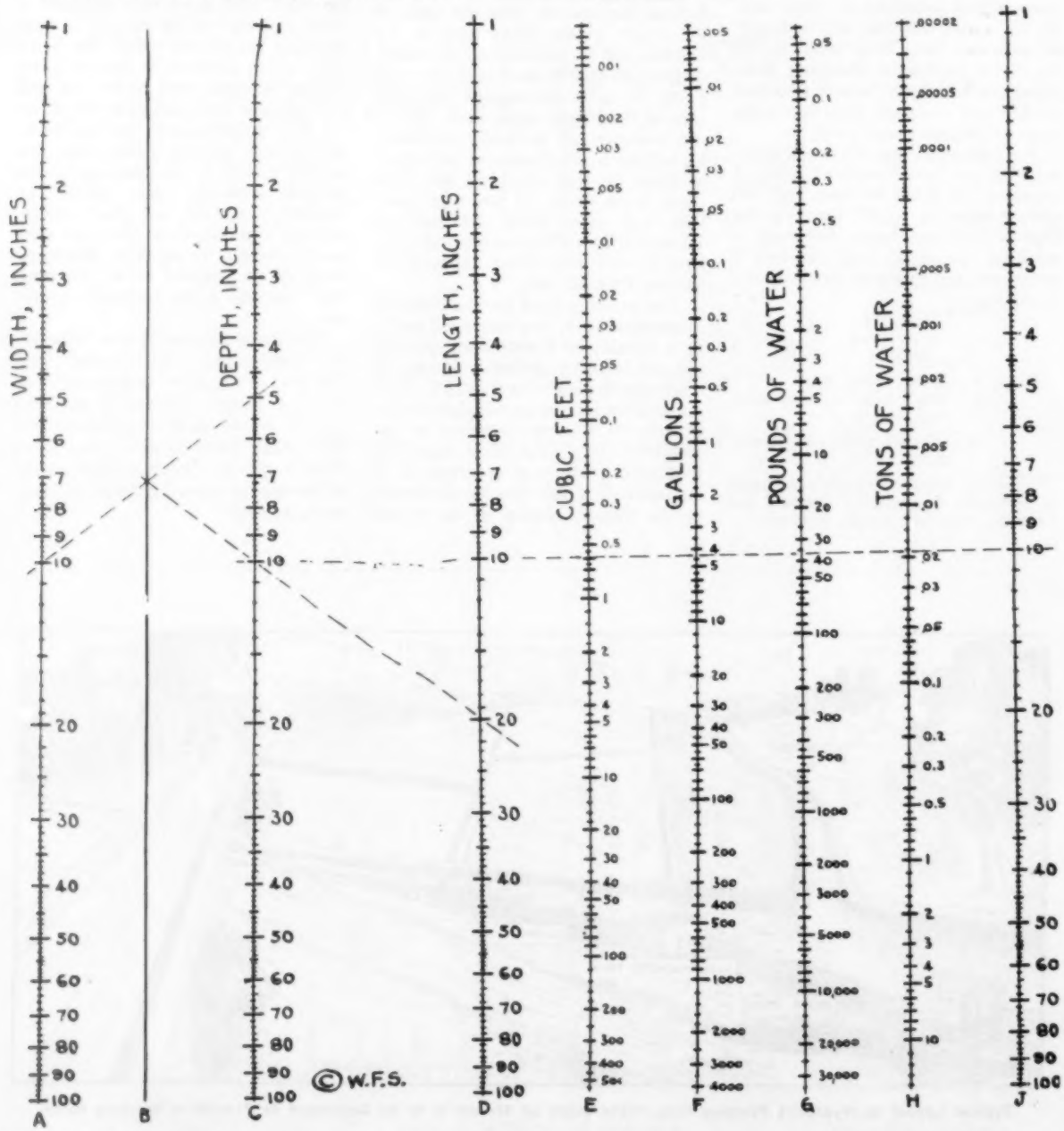
Column E shows that the tank has a volume of nearly 0.6 cu. ft.

Column F shows that the number of gallons is about 4.3.

Column G shows that if the tank contains water the weight will be about 37 pounds.

Column H shows that the number of tons of water is approximately .0185.

Contributed by W. F. Schaphorst, M.E., Newark, N. J.



Speed Chart for Water & Sewage Works

by W. F. SCHAPHORST, M.E.

Newark, N. J.

THIS chart has an almost endless number of applications in and around the water works plant for determining ordinary and extraordinary speeds. Where desired, its use may assist in speeding up conditions.

As every reader has doubtless observed, the speeds that are generally used in water works plants are in terms of feet per minute or per second or in rpm. We are left to "guess" as to miles per hour speeds or we must compute them laboriously in longhand or with a slide rule.

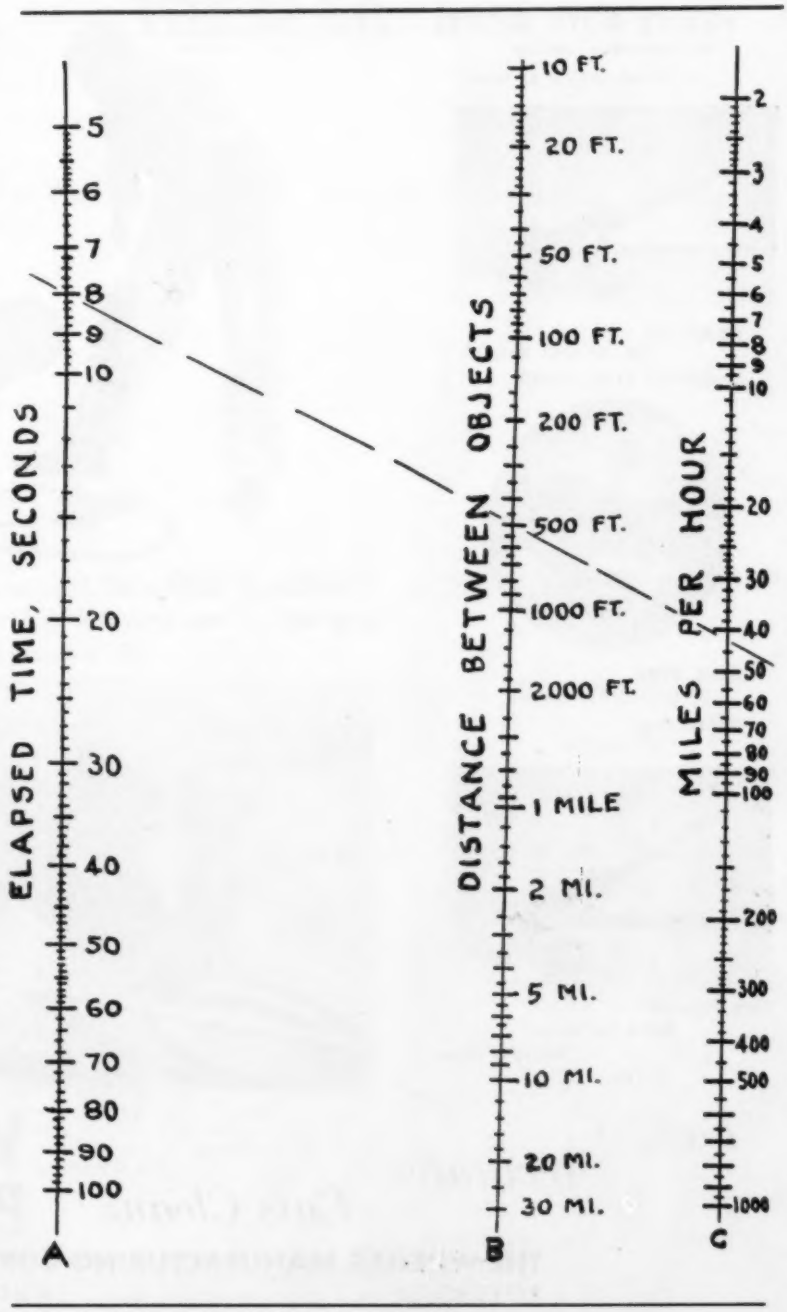
Charts giving feet per minute, such as water flow in pipes, are more or less common, but this writer has never seen a chart that gives miles per hour, so he developed this one.

For example, let us say that in your plant you have a coal conveying belt and you find that a given lump of coal on it travels between two fixed points in 8 seconds. You also find that the two points are 500 ft. apart. What is the speed of the belt?

The dotted line drawn across the chart shows how easily the problem is solved. Simply lay a ruler or straightedge across the chart, through the elapsed time, column A, and through the distance between the fixed points, column B, and the answer is instantly found in column C.

The columns are read in the same way that you read an ordinary thermometer. Thus, roughly, you would say that the dotted line cuts column C at 43, which means that the speed of the coal conveyor is 43 miles per hour.

As will be noted, the range of the chart is extremely wide—from 2 miles per hour to 1,000 miles per hour. But in addition its range can be extended indefinitely for lower or higher speeds by merely shifting decimal points. Thus, for example, if you should toss a piece of paper into a river at its center and find that the paper moves 500 ft. in 80 seconds, the same dotted line drawn across the chart tells us that the river at its center flows at 4.3 miles per hour. Or if it takes 800 seconds to cover the same distance the speed is 0.43 mile per hour. In other words, simply move the decimal point in column C as many places to the left as you move the point in column A to the right.



Ed. Note: This chart will also reveal the distance an object will travel in any given time if the speed in miles per hour is known. For example: at 10 mi./hr., in 1 minute (60 sec.) the line from 10 mi./hr. to 60 sec. passes through 900 ft. on "B" as the distance per minute. Or, if the speed is 35 mi./hr. and you wish to know how many seconds will be required for the object to travel 1000 ft. the line from 35 m.p.h. through 1000 ft. on "B" passes through 20 sec. on "A." The nomograph may be checked for accuracy by observing that the line from 1 min. (60 sec.) on "A" to 60 m.p.h. on "C" passes through the 1 mile mark on "B."

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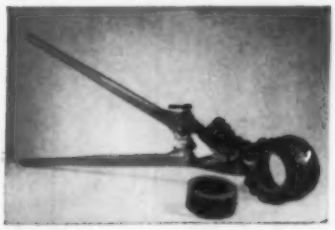
CHIMNEY FLUE LINER

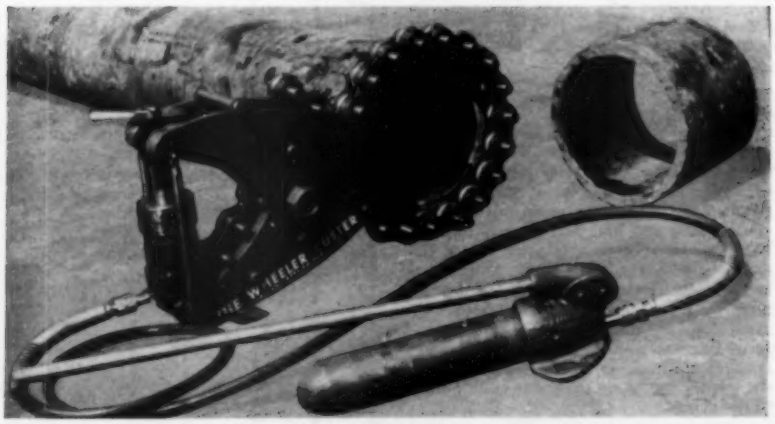
SOIL PIPE
2" thru 6" std. or XH
DURIRON
2" thru 8"



Clay Pipe—
Terra Cotta—
Concrete Pipe
2" thru 15"

HYDRAULIC MODEL
requires no vise—no turning
Just
"SQUEEZE & POP"

Capable of cutting 36" tile, cast iron soil pipe from 4" thru 15" and will cut cast iron AWWA water main thru 12" and 6" thru 10" transite pressure pipe



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BULLETINS and CATALOGS

For Copies of any of the Bulletins or Catalogs Listed Below, Circle the Corresponding Numbers on the Inquiry Reply Card in this Section.

1*R*

Acid Handling Pump—This 6-page bulletin describes the design features, corrosion-resistant materials of construction, applications, sizes and capacities of this acid handling pump.—Dorr-Oliver Inc.

2*R*

Acid Handling Pump—This catalog briefly describes the design features, operation and application of this positive displacement metering pump for sulfuric acid in concentrations up to 66° Baumé.—Precision Chemical Pump Corp.

3*R*

Activated Nuchar—12 page booklet on Powdered Activated Nuchar for Purification and Reclamation.—Industrial Chemical Sales Div., West Virginia Pulp and Paper Co.

4*R*

Activated Silica Sols Preparation—Series Sheet "A" covers jar test procedures for preparing activated silica sol from sodium silicate and ammonium sulfate as the reacting chemical. Sheet "B" details procedures for batch preparation of activated silica sol with such reactants as ammonium sulfate, alum, chlorine etc. Illustrations show flow diagrams.—Philadelphia Quartz Co.

5*R*

Activated Sludge—A technical study on the Kraus Process covers the dual aeration system for power savings and sludge interchange for beneficial use of supernatant liquor and elimination of bulking. Actual plant data. Design considerations.—Pacific Flush Tank Co.

6*R*

Activated Sludge—Catalog 100 describes the Cavitator for installations up to design populations of 1,000.—Yeomans Brothers Co.

7*R*

Activated Sludge Plant—The advantages of the Aero-Accelator (r) activated sludge plant, operational comparison figures and diagrams, performance records, suggested plant layouts and specifications, along with pictures of actual installations are all included in Bulletin 6510—Infilco, Inc.

8*R*

Aerator Clarifier—Bulletin 129 gives detailed information on the small compact activated sludge sewage treatment unit, to handle up to 500,000 gpd.—Chicago Pump Co.

9*R*

Aeration Equipment—Bulletins 175-A and 177 cover the Wide-Band Aeration System, featuring swing diffuser units and precision diffuser tubes.—Chicago Pump Co.

10*R*

Aeration Equipment—This booklet presents complete information on the development, design and application of both Walker Diffusair and Impingement aeration equipment. It includes discussions on channel aeration, grit aeration and details on the Walker Air Lift for return activated sludge pumping.—Walker Process Equipment Inc.

11*R*

Aerators—This bulletin gives a brief outline of equipment for the aeration and removal of gases and odor from water.—General Filter Co.

12*R*

Aer-Degritter—This brochure gives detailed information on the company's Aerated Grit Removal System.—Chicago Pump Co.

Use Accompanying Reply Card to Obtain Copies of these Bulletins.

13*R*

Air Compressor—Catalog 5740 presents the heavy Pneumatractor, a 125 cfm gasoline engine driven air compressor built into a wheel tractor. The catalog describes the use of a backhoe, front end loader, rotary brush, dozer blade and other accessories in conjunction with the compressor.—Schramm, Inc.

14*R*

Air Filter System—This brochure describes in detail the company's Air Filter System for Air Diffusion.—Chicago Pump Co.

15*R*

Air Lift Pump—Bulletin describes this low lift pump as simple and less costly to maintain than centrifugal pumps on lifts of 3 to 6 ft.—Walker Process Equipment, Inc.

16*R*

Air Relief Valves—A 28 page booklet describing the construction and operation of Crispin automatic air valves available for the control of air in lines handling liquids.—Multiplex Mfg. Co.

17*R*

Air Relief Valve—Bulletin F illustrates and describes the Rensselaer combined air and vacuum and air release valve.—Ludlow Valve Mfg. Co., Inc.

18*R*

Algaecide—A new simple, low-cost way to stop algae problems in cooling systems through use of No. 120 series algaecide is described in this bulletin.—Allis-Chalmers Mfg. Co.

19*R*

Alumnium Elevated Water Tank—This reprint describes the construction of an aluminum all-welded elevated water tank.—Graver Tank & Mfg. Co., Inc.

20*R*

Aluminum Floor Grating—A bulletin discussing riveted, pressure locked, types of aluminum floor grating. General instruction for ordering and charts on safe loads are given. Borden Safety steps are also discussed.—Borden Metal Products Co.

21*R*

Asbestos-Cement Pipe Accessories—Bulletin describes company's complete line of products designed for use with asbestos-cement pipe.—Smith-Blair, Inc.

22*R*

Asbestos-Cement Pipe—A brief history of the use of asbestos and the advantages of "Century" asbestos-cement pipe. A chart of standard sizes and classes is included.—Keasbey & Mattison Co.

23*R*

Asphalt Liner—Literature describes prefabricated asphalt liner, called the Aqualiner, for heavy duty service in the positive containment of water, brines, sludges, wastes or sewage.—Presstite-Keystone Engineering Products Co.

24*R*

Automation—This bulletin discusses automatic control of filter operation with interlocking safety devices to prevent overflow of clearwell or dangerously low filter levels. It presents the "C.-A.-P. System" instruments.—Infilco Incorporated.

25*R*

Bacteria Free Packing—A descriptive leaflet on Fibrex, an approved sanitary packing.—Hydraulic Development Corp.

26*R*

Ball & Socket Cast Iron Pipe—This bulletin describes the Clow ball & socket cast iron pipe for river crossings and other uses where full 15-degree turning deflection is required.—James B. Clow & Sons, Inc.

27*R*

Barminutor—Bulletin 185-0 illustrates and describes advantages, principles of operation, applications, mechanical descriptions, detailed specifications and other information on the company's Barminutor comminuting machines for use in rectangular channels.—Chicago Pump Co.

28*R*

Bar Screens—These two bulletins discuss and illustrate Rex Heavy-Duty Bar Screens and front-cleaned bar screens.—Chain Belt Co.

29*R*

Bar Screens—This catalog covers the screening of sewage in both small and large plants. Also included are data on traveling water screens.—Jeffrey Mfg. Co.

30*R*

Bascule Gate— A 12 page bulletin with dimensions, description and typical installations of this crest gate for pond level and flood control.—S. Morgan Smith Co.

31*R*

Biofilters—Bulletin 7313 on small scale biofiltration with Dorr-Oliver Duo treatment units providing complete sewage treatment for institutions, housing developments and turnpike service areas.—Dorr-Oliver Inc.

32*R*

Brinemaker—This catalog illustrates and describes various types of brine making tanks and wet storage systems available to salt users.—Morton Salt Co.

33*R*

Carbonation—A handbook on carbonation of lime softened waters. Includes discussion of the background, chemical reactions, methods and problems in carbonation. Corrosion, due to impurities in CO_2 produced by certain methods, is thoroughly covered with tables giving corrosion resistance of various metals.—Walker Process Equipment, Inc.

34*R*

Cast Iron Pipe—Catalog gives full details of weights and dimensions of "Sand-Spun" centrifugal cast iron pipe, cast iron fittings and specialties.—R. D. Wood Co.

35*R*

Cast Iron Pipe—Complete line of Cast Iron Pressure Pipe in sizes of 3 to 24 inches diameter is listed in catalog 54. Complete specifications and construction details.—Alabama Pipe Co.

36*R*

Cast Iron Pipe—This illustrated booklet provides pictorial proof of the ruggedness and durability of cast iron pipe in water supply and distributions; sewer mains; and industrial service.—Cast Iron Pipe Research Assn.

37*R*

Cast Iron Pipe in Sewerage Systems—This 52 page booklet shows instances of the use of cast iron pipe in sewerage systems.—Cast Iron Pipe Research Assn.

38*R*

Catch Basins—Several styles and sizes of catch basins are described. The bulletin also states that special lettering is available.—Clarksville Foundry & Machine Works

39*R*

Cathodic Protection—A series of three bulletins on cathodic protection: "Fighting Corrosion with Corrosion", "Cath-O-Chem System", and "Cathodic Protection for Water Works Plants."—Electro Rust-Proofing Corp.

40*R*

Celite Filtration—A 12-page brochure describing and illustrating the advantages of Celite diatomite filter aids in producing clear, pure potable water,

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controlling process water clarity, and removing harmful impurities from plant waste.—Johns-Manville Corp.

41*R*

Cement Pipe Lining—A catalog describing the Centriline Process for pipes 4" to 144" including information on the new Centriline machine for placing a continuous cement mortar lining inside of all types of pipe in place. Bulletin includes illustrations of cleaning and lining equipment, hydraulic data and sample specifications for doing the work.—Centriline Corp.

42*R*

Centrifugal Pumps—This 20-page bulletin describes monobloc, single and two stage, centrifugal pumps in sizes ¾ to 6 inches. Drawings and rating curves are also included.—Worthington Corp.

43*R*

Ceramic Glazed Facing Tile—General Catalog S-58 gives complete details on the many diversified uses of Natco Ceramic Glaze Vitritile. This completely sanitary and low maintenance face tile is suitable for virtually all types of interior walls.—Natco Corp.

44*R*

Chemical Feeders—Bulletin (3156) describes dry chemical feeders for the feeding of coagulants and other chemicals to Precipitators, detention tanks, etc. These feeders are of the volumetric displacement type—Permutit Co.

45*R*

Chemical Feeders—Bulletin 30-H12A on gravimetric loss-in-weight feeders; Bulletin 35-G5A on belt gravimetric feeders; Bulletins 20-P2 and 50-K57A on volumetric feeders; all for adding chemicals for water or waste-treatment.—Omega Machine Co.

46*R*

Chemical Feeders—This bulletin describes positive displacement pumps for feeding corrosive fluids. Bulletin 1106-7—Proportionees, Inc.

47*R*

Chemical Feeders—This catalog pictures and describes electric vibrating feeders for the feedng of dry chemicals in water and sewage treatment plants.—Jeffrey Mfg. Co.

48*R*

Chemical Feeders—Publ. No. TP. 39M-5 describes volumetric dry feeders.—Wallace & Tiernan Inc.

49*R*

Chemical Pump—This catalog briefly describes the design features, operation and application of this positive displacement metering pump for chemical solutions.—Precision Chemical Pump Corp.

50*R*

Chemical Treatment—Bulletin A-705 discusses the use of chemicals in water and sewage treatment.—Columbia-Southern Chemical Corp.

51*R*

Chlorine Feeders—A series of bulletins on Chlorinizers, for feeding chlorine gas and other gases like ammonia, sulfur dioxide, etc. Capacities from 4 to 8000 lbs. per 24 hours.—Builders-Providence. Inc.

52*R*

Chlorine Feeders—A series of catalogs on chlorinators and accessory equipment, ranging in application from swimming pools to high capacity industrial requirements.—Fischer & Porter Co.

53*R*

Chlorine Feeders—Cat. File Nos. 20.100 50.110, present mechanical diaphragm vacuum type solution feeder and chlorine flow recorder.—Wallace & Tiernan Inc.

54*R*

Chlorine Feeders—Bulletins are available on V-Notch variable orifice chlorinators.—Wallace & Tiernan Inc.

55*R*

Chlorine—A bulletin describing the physical properties, handling methods, uses and containers.—PennSalt Chemicals Corp. Pa.

56*R*

Chlorine—Bulletin containing general information on the properties, containers, and handling of liquid chlorine.—PennSalt Chemical Corp. Wash.

57*R*

Chlorine Dioxide—A booklet discussing in detail the removal of tastes and odors by chlorine dioxide treatment and its bactericidal properties, methods of treatment and application. Economic factors and general installation instructions are also included.—Industrial Chemicals Div., Olin-Mathieson Chemical Corp.

58*R*

Chlorine—General information, prices, list of local distributors, shipping containers on liquid chlorine, calcium hypochlorite, and sodium hypochlorite.—John Wiley Jones Co.

59*R*

Chlorine Hand Book—76 pages, hard cover-describes equipment for handling chlorine, including shipping containers, safety and first aid measures. Also covers preparation of lime and sodium bleaches and analytical data on hypochlorites. Bulletin No. 125—Hooker Chemical Co.

60*R*

Chlorine Handling—Bulletin A-505 discusses the problem of the Safe Handling of Chlorine.—Columbia-Southern Chemical Corp.

61*R*

Chlorine Residual Recorder—Catalog 50.250 describes the WT Residual Chlorine Recorder as an instrument for measuring residual chlorine amperometrically in a continuous sample and recording the reading in parts per million on a 24 hour circular chart. Advantages, case histories, design features, operation and technical data are included.—Wallace & Tiernan Inc.

62*R*

Chlorine Wall Chart—Chart describes container valves, leak detection, first aid and accident procedures.—PennSalt Chemicals Corp., Pa.

63*R*

Chlorine Wall Chart—This chlorine wall chart lists some of the important things to do in handling liquid chlorine in cylinders, ton containers and tank cars. It covers first aid and emergency procedures. The chart is clearly illustrated with diagrams of chlorine container valves. Bull. 132—Hooker Chemical Co.

64*R*

Clarification—Bulletin #5811 illustrates and describes the five basic "Contraflo" designs and their application in water and waste treatment plants.—General Filter Co.

65*R*

Clarifiers—This bulletin 35-D describes two settling type clarifiers for both circular and rectangular tanks, equipped with both skimming and sludge scraping mechanisms.—Hardinge Company, Incorporated.

66*R*

Clarifiers—Verti-Flo clarifier tanks are covered in two bulletins. Efficient, low cost Verti-Flo is designed to clarify plant water, reclaim process water, eliminate pollution, or reclaim valuable materials.—Chain Belt Co.

67*R*

Clarifier and Softener—Technical Reprint T-135 discusses the design of water clarifiers and softeners and presents details on the considerations that must be studied in designing a unit that is properly sized to handle the present and future load requirements—Graver Water Conditioning Co.

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68*R*

Clarifier Mechanisms—This bulletin describes the conventional center drive type clarifier mechanisms, and, rectangular drag-line sludge collectors, and the "Streamline".—Yeomans Brothers Co.

69*R*

Clarifiers, Spiraflo—This 8-page catalog covers the exclusive features of this settling tank for either primary or final tank installations.—Yeomans Brothers Co.

70*R*

Clariflocculator—This bulletin describes the physical characteristics, principle of operation, types, sizes and advantages of this combination flocculation and clarification mechanism. Included are photographs of operating installations and line and wash drawings of standard units.—Dorr-Oliver Inc.

71*R*

Clean Swimming Pools—This circular gives helpful information on the treatment of swimming pool water and describes Taylor equipment for chlorine and pH testing.—W. A. Taylor & Co.

72*R*

Coagulant Aids—Nomograph—"N-Sol" Process Coagulant aid preparation nomograph in chart form suitable for posting. Used to determine sodium silicate requirements, quantity of reacting chemical, necessary dilutions, expected alkalinity and preparations and feed rate for flow variations. All popular reacting chemicals listed.—Philadelphia Quartz Company.

73*R*

Coagulants—Technical Reprint T-138 discusses the selection of coagulants and chemical treatment for softening and coagulation in high-rate units. This article presents the different types of chemicals used, their properties and the proper method of testing each.—Graver Water Conditioning Co.

74*R*

Coal and Ash Handling—Two folders and a catalog on coal and ash handling layouts; also a catalog on chains, and a series of questions and answers on ash handling.—Beaumont-Birch Co.

75*R*

Coating, Protective—A 4-page bulletin on Rexon coating no. 2 for protecting concrete pipe inside and out, from corrosive attack—Hamilton Kent Mfg. Co.

76*R*

Coatings, Protective—Bulletin 100 describes a wide range of protective coatings. Included in Bulletin are the four classes of corrosive areas broken down as to severity. Also included is description of coatings, physical and chemical properties, and suggested applications.—Carboline Co.

77*R*

Coating, Protective—The use of Carbomastic epoxy-tar coatings have various advantages in conditions such as high humidity, hydrogen sulphide, water immersion, tank linings and heavy duty maintenance are shown in Bulletin 803. Corrosion charts show resistance of Carbomastics in each atmosphere—Carboline Company

78*R*

Coatings, Protective—This bulletin discusses and illustrated Dimecote #3, the 100% inorganic zinc silicate coating that provides near-permanent protection to steel exposed to severe conditions of rust, weathering and salt air, as well as fresh and salt water.—Amercoat Corp.

79*R*

Coatings, Protective—This data sheet describes Amercoat #88, designed to protect concrete, plaster, masonry from water penetration, staining, weather etc.—Amercoat Corp.

80*R*

Comminuting Devices—Bulletins 5100 and 5150 discuss the "Griductor" and "Rotagrator" screens and comminutors with many illustrations of design principles.—Infilco Incorporated

81*R*

Concrete Tank Design—Bulletin T-19—An 8-page Technical booklet on the design of prestressed concrete tanks for water supply use.—The Preload Company, Inc.

82*R*

Construction Tools—Illustrated 16 page catalog 5850 on rack drills; wagon drills; pavement breakers; clay spades; trench diggers; backfill tampers; drill steels; rock bits; air hose; and couplings.—Schramm, Inc.

83*R*

Comminutor—Bulletin 185-D presents complete data, details and installation information on the company's comminutor.—Chicago Pump Co.

84*R*

Concrete Pressure Sewer Pipe—A folder discussing features and standards of concrete pressure sewer pipe.—Price Brothers Co.

85*R*

Concrete Pressure Water Pipe—A booklet explaining and illustrating the proper method of laying concrete pressure pipe. The steps discussed are: digging the trench; checking grade; handling the pipe; lubricating joint rings; making the joint; checking the gasket; grade and line changes; completing the joint; bedding the pipe; and the use of pull jacks.—Price Brothers Co.

86*R*

Concrete-Treating—Folder covers use of silicate of soda to make concrete harder, dustproof, acid-resistant and moisture-resistant. Cleaning concrete also detailed.—Philadelphia Quartz Company

87*R*

Controllers—Catalog C100-1A describes Tel-O-Set Miniature pneumatic instruments for measurement and control in water filtration plants—Minneapolis-Honeywell Regulator Co.

88*R*

Controllers—Catalogs 900 and 950 include detailed specifications and control action descriptions for both mechanical and pneumatic controllers.—Simplex Valve & Meter Co.

89*R*

Control Panels—A booklet (4178) which describes the many types of control cubicles furnished for intergrating and centralizing the control of water-conditioning systems. These cubicles provide semi-automatic or fully automatic control—The Permutit Co.

90*R*

Copper Sulphate—Two booklets on the use of copper sulphate. "Copper sulphate in control of Microscopic Organisms", and "Copper sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains."—Phelps Dodge Refining Corp.

91*R*

Copper Sulphate—A 13-page booklet describing the use and application of sulphate in water treatment and algae control, and containing charts of chemicals required for various treatments.—Tennessee Corp.

92*R*

Corrosion Control—This bulletin presents the uses and advantages of Calgon Composition TG in treating cooling water systems and municipal water systems to control the formation of corrosion—Calgon Company Div. of Hagan Chemicals & Controls, Inc.

93*R*

Couplings, Asbestos-Cement Pipe—Features and installation instructions for the use of Century "Fluid-Tite"

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couplings are graphically presented along with a chart of standard sizes.—Keasbey & Mattison Co.

94*R*

Curb Lock—A folder on the Bremer Curb lock that positively controls water cut offs. The unit will not corrode and can be used over and over.—Bremer Brease, Inc.

95*R*

D. C. Motors—This bulletin describes direct-current motors, ½ through 200 hp, and motor-generator sets up through 200-kw output.—Allis-Chalmers Mfg. Co.

96*R*

Defoamant and Foam Control—Technical data sheet provides information on Foamwilt, an effective all-weather defoamant. Desirable characteristics and test results from various sewage plants are given, along with physical properties.—Fine Organics, Inc.

97*R*

Demineralization—This 20-page bulletin outlines the principles of demineralization by ion exchange. Gives details of equipment arrangement, characteristics of ion exchange resins, equipment and resin specifications.—The Permutit Co.

98*R*

Demineralizers—Bulletin WC-111 discusses the design, theory, and equipment of ion exchange systems in detail. A cost estimating curve, system selection chart and other features are also included.—Graver Water Conditioning Co.

99*R*

Densludge Digestion System—A 16-page bulletin describes the development, equipment, operation, typical applications and design loadings of this new sewage sludge digestion system and the means by which digester capacity requirements are substantially reduced.—Dorr-Oliver Inc.

100*R*

Deodorants—A paper and two folders discuss the effective reduction of sewage and waste odors and the science of Osmics.—Airkem, Inc.

101*R*

Deodorants—Technical literature on Cifon, N. Y. and Arodon used as deodorants in sewage disposal plants.—Fine Organics Inc.

102*R*

Desanding System—Literature describes and illustrates the DorrClone desanding system for water supplies.—Dorr-Oliver, Inc.

103*R*

Diatomite Filters—Bulletin 1860-PI on diatomaceous earth filters.—Proportioneers, Inc.

104*R*

Diatomite Filters—Design, features and advantages of diatomaceous earth filtration are discussed in this bulletin. Sizing table and typical specifications are included.—Graver Water Conditioning Co.

105*R*

Differential Pressure Transmitter—Catalog 10B1465 describes new force-balance Differential Pressure Transmitter featuring measuring circuit parts completely sealed off in silicone oil and adjustable damping directly within the measuring circuit itself.—Fischer & Porter Co.

106*R*

Diffusion Plates & Tubes—This booklet describes fully porous ceramic-bonded plates and tubes for both air and gas diffusion. Also covered is their application to the activated sludge process and to other processes requiring uniform bubble diffusion.—The Carborundum Co.

107*R*

Digester Cover Roofing—A new concept in roofing for digester floating covers is described in bulletin 333. This roofing is said to provide longer life with better insulation and minimum maintenance.—Pacific Flush Tank Co.

108*R*

Digester Sludge Heater—Bulletin tells how this Heater combines concentric tube heat exchanger, separate fire tube boiler and control panel to give absolute automatic control over each function.—Walker Process Equipment, Inc.

109*R*

Digestion Equipment—Bulletin 185-D describes in detail advantages, design, construction and operation information on the company's Catalytic Reduction Process for accelerated sludge digestion.—Chicago Pump Co.

110*R*

Ditcher—A catalog featuring the improved Gar Wood-Buckeye Model 403 utility ditches—Gar Wood Industries, Inc.

111*R*

Double Suction Pumps—This bulletin describes and illustrates type M horizontally split case double suction pumps.—C. H. Wheeler Mfg. Co., Economy Pump Div.

112*R*

Drafting, Color-Coded—How reading of complicated drawings can be greatly simplified by color-coding is described in bulletin on Mars-Lumochrom pencils. All 24 colors reproduce perfectly; drawings are waterproof, easily erasable, do not smear or fade.—J.S. Staedtler, Inc.

113*R*

Drafting on Mylar—Drafting that is smearproof on matte-surface film is described in literature on revolutionary Mars-Lumograph Duralar pencil. Has plastic, rather than graphite, base. Drawings are completely washable and erasable, won't smudge, reproduce as sharp as India Ink originals.—J. S. Staedtler, Inc.

114*R*

Drilling Machine—Folder describes the All New Mueller C1-12 Drilling Machine. Revolutionary feed control—completely automatic; boring bar cannot overtravel. Automatic or hand feed. Full Vision indicator shows amount of travel at all times. Hand or power driven. Makes cuts from 2" to 12" in any size or kind of main.—Mueller Co.

115*R*

Dry Chemical Feeders—Bulletin 217 describes the operating principles and design characteristics of Type E dry chemical feeders. Bulletin 250 discusses lime mixers and feeders in which mixing is accomplished by agitators revolving in the vertical plane to prevent stratification.—Infilco Incorporated

116*R*

Effluent Sampler—Bulletin describes the sampler and gives operating instructions.—Phipps & Bird, Inc.

117*R*

Electrical Control Panels—This bulletin describes typical custom electrical control panels for sewage lift stations, water and sewage plants.—Smith & Loveless, Inc.

118*R*

Elevated Steel Tanks—A 20-page brochure describing Horton ellipsoidal bottom elevated steel tanks of welded construction. Illustrates a number of industrial and municipal tanks, describes dual service of tanks for general use and fire-protection. Lists table of standard capacities up to 500,000 gallons.—Chicago Bridge & Iron Co.

119*R*

Elevated Steel Tanks—A 24-page booklet discusses Horton Elevated Steel Tanks of Large Capacity and describes the advantages of using large elevated steel tanks to provide gravity pressure. Also contained, detailed information on the design and construction of the tanks

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and 12 photographs of actual installations, a table of sizes, and page of drawings showing construction details.—Chicago Bridge & Iron Co.

120*R*

Elevated Steel Tanks—This 20-page booklet includes dimensional data and capacities for 6 basic tank types, in addition to many installation photographs and descriptions. A cut-away view shows such accessory equipment for these tanks such as swivel ladder, stub overflow, steel balcony and vent.—Pittsburgh-Des Moines Steel Co.

121*R*

Elevated Storage Tanks—A brochure, "Cole Shallow Depth Steel Tanks" gives photographs and description, and table of capacities and sizes of hemispherical, self-supporting bottom tanks.—R. D. Cole Manufacturing Co.

122*R*

Elevated Water Tanks—A 16-page brochure describing the Watersphere and Waterspheroid. The modern structures are used in municipal and private water systems to provide gravity pressure for general service and fire protection, and this use is described in the booklet. A portion of the booklet illustrates the "skyline advertising" use of these structures.—Chicago Bridge & Iron Co.

123*R*

Engine Diesel—Literature describing a turbo-supercharged opposed-piston diesel engine, said to be the smallest and lightest commercial diesel in its hp range.—Fairbanks, Morse & Co.

124*R*

Engines—A series of 4 bulletins describing Climax 4, 6, 8 and 12 cylinder gas engines in a range of sizes up to 600 hp. These engines are capable of operation on natural gas, butane, sewage gas, gasoline or a combination of any two of these fuels.—Climax Engine Manufacturing Co.

125*R*

Engines—A series of 4 bulletins describing Roiline 6, 8 and 12 cylinder gas engines in a range of sizes up to 685 hp. These engines are capable of operation on natural gas, butane, sewage gas, gasoline or a combination of any two of these fuels.—Waukesha Motor Co.

126*R*

Engines, Sewage Plant—A 20-page bulletin showing dual fuel engines, diesel engines and spark ignition engines. Contains engine selection chart, comparison fuel gas analysis chart and others.—Worthington Corp.

127*R*

Enzymes—A 9 page booklet discusses the theory and application of enzyme and bacterial additives to sewage wastes.—Activated Chemicals & Products Co.

128*R*

Electric Motors—This bulletin contains the line of U.S. Motors. Descriptions and full-color illustrations are included of open-type Uniclosed designs, totally-enclosed and explosion-proof types, Varidrives, Syncrogears, and right-angle worm gear models; also vertical motors and Verticlosed hollowshaft types.—U.S. Electrical Motors, Inc.

129*R*

Ferric Chloride, Anhydrous—A general information bulletin on the use of anhydrous ferric chloride in sewage and water treatment.—Pennsalt Chemical Corp. Wash.

130*R*

Ferric-Floc—A 38-page booklet describing the use and application of ferric sulphate in all phases of coagulation.—Tennessee Corp.

131*R*

Filter, Automatic Backwash—Bulletin-46-A illustrates and describes how this automatic backwash sand filter traveling carriage cleans the compartmented filter bed section by section without interrupting the normal filtering operation.—Hardinge Company, Incorporated.

132*R*

Filter, Automatic Valveless—This bulletin describes the completely automatic gravity sand filter that uses no valves, pumps or flow controllers.—The Permutit Co.

133*R*

Filter Media—Bulletin on "Anthrafilt" tells the reasons why selected, graded, crushed anthracite is superior to sand as a filtering material.—Anthracite Equipment Corp.

134*R*

Filter Operating Console—Product Specification G71-9 describes styles of steel control consoles for operation of rapid sand filters. Available in four standard colors, each console has inclined surface for optimum readability of instruments and efficient operation of hand adjustments.—Bailey Meter Company.

135*R*

Filter Operating Tables—Detailed description and typical illustrations of conventional hydraulic filter control tables—F. B. Leopold Co., Inc.

136*R*

Filters—General information on Roberts filters for municipal water purification, industrial water rectification, swimming pool recirculating systems and pressure filters.—Roberts Filter Mfg. Co.

137*R*

Filters, Pressure—Bulletin 2225 describes the operation and design features of pressure filters, both vertical and horizontal. Contains details of auxilary equipment including Permutit Multiport Valve, also installation photos and specifications.—The Permutit Co.

138*R*

Filter Table, Automatic—Bulletin 2200 is a 4-page catalog which furnishes detailed information on the use and operation of the Simplex Electro Pneumatic Filter Control Table.—Simplex Valve & Meter Co.

139*R*

Filter Underdrains—Brochure gives complete information on "Criscrete" filter underdrains.—M C G Company.

140*R*

Filter Underdrains—Complete information and typical drawings on Leopold compound duplex glazed tile filterbottoms—F. B. Leopold Co., Inc.

141*R*

Fire Hydrants—44 page bulletin no. 5710 gives complete information on the Darling B-50-B Fire Hydrants with Ball Bearings for ease of operation and "O" Rings instead of the usual stuffing box.—Darling Valve & Mfg. Co.

142*R*

Fire Hydrants—Literature on Mathews modernized, Mathews flanged barrel and R. D. Wood swivel joint fire hydrants conforming to latest AWWA specifications and of designs to meet any requirement.—R. D. Wood Co.

143*R*

Fire Hydrants—This bulletin describes the Corey-type fire hydrants and Iowa waterworks valves.—Iowa Valve Co.

144*R*

Fire Hydrants—This bulletin illustrates and describes the complete line of compression type fire hydrants made by the company.—A. P. Smith Mfg. Co.

145*R*

Fire Hydrants—This 18-page catalog illustrates and describes the Ludlow slide gate type of hydrant.—Ludlow Valve Manufacturing Co., Inc.

146*R*

Financing Water and Sewage Works—This booklet is designed planning and financing water and sewage works. It

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IF YOU WISH TO RECEIVE FURTHER INFORMATION ON PRODUCTS ADVERTISED CIRCLE KEY BELOW

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WATER & SEWAGE WORKS

W. & S. W.—REFERENCE NUMBER—1958

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points out the need for sanitation facilities and stresses the revenue bond method of financing. Also discussed are factors to be considered in a determination of fair rate schedules for water and sewage charges.—Portland Cement Association

147*R*

Fire Hydrants & Gate Valves—Compact brochure describes all the features of Mueller AWWA Improved Fire Hydrants and AWWA Gate Valves. Many other illustrations show the types of hydrants available, and the more popular end combinations to be had in gate valves, whether with "O" ring seals or conventional packing—Mueller Co.

148*R*

Floating Covers—A bulletin that covers in 40 pages the theory of control digestion with digester design considerations, digester operation and floating cover construction details.—Pacific Flush Tank Co.

149*R*

Floating Covers—This brochure gives design and application data on positive, non-tipping construction of Chicago-Wiggins Pontoon Digester Floating Covers.—Chicago Pump Co.

150*R*

Float-Treat System—For water, sewange and wastes treatment. Bulletin describes in detail the process in which suspended organic matter and usual chemical flocs are removed from process liquids by flotation.—Chain Belt Co.

151*R*

Flocculation—Bulletins 2W66 and 2W72 cover impeller type and reel type flocculation units and rapid mixers for water and waste treatment.—Walker Process Equipment, Inc.

152*R*

Flocculation—This catalog described the Floctrol process. Drawings, photos and dimensions are included.—Jeffrey Mfg. Co.

153*R*

Flocculation Equipment—An 8-page booklet, "Equipment For Chemical Flocculation" illustrates and discusses Link-Belts line of conveyors and elevators for handling chemicals and flash and straightline mixers.—Link-Belt Co.

154*R*

Flocculation Equipment—This bulletin covers the pretreatment of water. Rex Floctrol design and arrangement are covered in detail. Information on Rex Slo-Mixers and Rex Flash-Mixers is included.—Chain Belt Co.

155*R*

Flocculators—Bulletin 6971 contains a description of Dorr-Oliver equipment used to perform the two basic steps of flash mixing and flocculation.—Dorr-Oliver Inc.

156*R*

Floor Grating—A bulletin discussing riveted, pressure locked, types of aluminum floor grating. General instruction for ordering and charts on safe loads are given. Borden safety steps are also discussed.—Borden Metal Products Co.

157*R*

Floor Grating—Catalogs available on steel, stainless and aluminum grating. Contains safe load tables, how to order information, specifications. Stair tread data and Drain Grating.—Kerrigan Iron Works, Inc.

158*R*

Flotation—This bulletin discusses the Graver "Aeroflotor" and shows the design features. The various uses and advantages of flotation are discussed.—Graver Water Conditioning Co.

159*R*

Flow Measurement—Bulletins 402, 500, 700, 750, and 950 cover equipment manufactured by the company for fluid flow measurement.—Simplex Valve & Meter Co.

160*R*

Flow Measurement—Bulletin 115-LIA on Dall Flow Tube; Bulletins 110-N1 on Venturi Tubes; 135-F2A Kennison Nozzles; and 380-K4A on Propeloflo meters.—Builders-Providence, Inc.

161*R*

Flowmeter, Magnetic—Catalog 10D1416 discusses principle and operation of magnetic flowmeters. Gives advantages and specifications of F & P unit.—Fischer & Porter Co.

162*R*

Flow Recorder—Bulletin 25 describes liquid flow recording, totalizing and indicating meters for open channel measurement. May be either direct float-operated or remotely controlled.—Leupold and Stevens Instruments Inc.

163*R*

Flow Tubes—The Gentile Flow Tube, used for metering water, air, slurry, raw sewage sludge, paper stock, etc. Advantages of the flow tube are given, along with a performance table, head loss and differential charts. Photographs of actual installations and cut-away drawings are included.—Foster Engineering Co.

164*R*

Fluo-Chlorinator—Catalog 70F140 describes Fischer & Porter Fluo-Chlorinator designed for the simultaneous addition of both chlorine and dissolved fluorides, Either substance can be added separately—Fischer & Porter Co.

165*R*

Fluoride Feeders—This bulletin describes the Omega fluoridzer for accurate continuous volumetric feeding of fluoride compounds. —Omega Machine Co.

166*R*

Gasket Type Joint, Cast Iron Pipe—A brochure on Fastite joint pipe for water, sewage and other liquid service. The brochure gives a complete description of pipe joint, photograph and text show the proper methods of assembly in the field, specifications and photograph of typical installations. Tables containing weights, working pressures and recommended deflections are also included—American Cast Iron Pipe

167*R*

Gaslifter, Digester Circulator—Bulletin describes the gaslifter as the simplest and most efficient digester mixer available—Walker Process Equipment, Inc.

168*R*

Gas Safety Equipment—This bulletin provides capacity curves along with detailed drawings of a complete line of gas safety equipment designed expressly for sewage sludge gas. The bulletin also pictures a number of typical installations and provides a standard layout of a digester gas piping system.—Pacific Flush Tank Co.

169*R*

Gate Valve, AWWA—This bulletin illustrates and describes list 13A AWWA Rensselaer gate valve as well as high and low pressure valves.—Ludlow Valve Mfg. Co. Inc.

170*R*

Gate Valves—This 36-page bulletin illustrates and describes AWWA gate valves, high and low pressure valves, as well as miscellaneous waterworks appurtenances.—Ludlow Valve Manufacturing Co., Inc.

171*R*

Gate Valve, Bonnetless—Literature describes fabricated bonnetless gate valve, designed for handling fibrous, viscous and slurry type flows.—DeZurik Corp.

172*R*

Generators—This booklet has specifications of gasoline-engine-driven AC generators along with descriptions of Homelite's full line of carryable con-

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struction equipment.—Homelite, Div. of Textron Inc.

173*R*

Glazed and Unglazed Face Brick—Light Construction Catalog SB-58 describes and illustrates the wide range of Natco Standard, Roman and Norman Brick—Natco Corp.

174*R*

Gratings—Booklet discusses in detail the construction, design and load capacity of corrosion resistant aluminum gratings. Also contains information on aluminum stair and ladder treads.—Washington Aluminum Co.

175*R*

Gratings—Catalog #5573 on Gold Nugget Welded Grating contains engineering data as to load capacity, fabrication, etc.—Globe Co.

176*R*

Gratings—Catalog #35812 on Grip-Strut Non-Skid Grating contains engineering data as to load capacity, fabrication etc.—Globe Co.

177*R*

Gratings, Drainage—This literature lists many sizes, types and thicknesses in tabular form to help make a selection from numerous patterns.—Clarksville Foundry & Machine Works.

178*R*

Grinders—Complete data on grinders for sewage screenings is given in this catalog. It also covers sludge collectors and screens.—Jeffrey Mfg. Co.

179*R*

Grit Collectors—The 5 basic types of Rex grit collectors, making a broad comprehensive line, are covered in this bulletin.—Chain Belt Co.

180*R*

Grit Removal—This bulletin and technical supplement describe the grit conveyor, grit hydrowash, grit elevator and "American" Camp regulator for grit removal by velocity regulation and mechanical means.—American Well Works.

181*R*

Gunite—This 48-page booklet illustrates Gunite for repair and restoration to all existing concrete and masonry structures. Typical specifications are listed.—Pressure Concrete Co.

182*R*

Heat Exchangers—A 28-page bulletin presents a consise explanation of effective digester heating, scum control and operation of the P. F. T. Sludge Heater. Bulletin includes a method of computing size of heater and heat exchangers and table with complete size and operating data.—Pacific Flush Tank Co.

183*R*

Heat Exchanger—Bulletin 6281 on the spiral heat exchanger, an external element of the spiral flow type for controlling digestion tank temperatures—Dorr-Oliver Inc.

184*R*

Heat Exchanger—This brochure illustrates and describes the Cyclotherm Digester heater and heat exchanger.—Chicago Pump Co.

185*R*

Heat Transfer—This brochure gives detailed information on Chicago-Selas heat transfer system for superior sludge heating service.—Chicago Pump Co.

186*R*

Hi-Cone Sludge System—Catalog 6660 details operating and performance data of the Hi-Cone system. Complete specifications and layout dimensions are also included.—Yeomans Brothers Co.

187*R*

High Capacity Chlorinator—20 page catalog 70-15 describes features, construction and application of vacuum-type, solution-feed, high capacity gas chlorinator suitable for manual, semi-automatic or fully automatic operation in capacities from 60 to 8,000 pounds of chlorine per 24 hours.—Fischer & Porter Co.

188*R*

Horizontal Compressors—This 24-page bulletin discusses single stage, 10-150 psi, 5-2000 cfm compressors. It also contains drawings and specifications.—Worthington Corp.

189*R*

Hydrant's Fire—Twelve page circular describing standard, traffic and flush models of fire hydrants, how to install, lengthen and repair, and special features. Circular No. 22—M & H. Valve and Fittings Co.

190*R*

Hypochlorination—This booklet discusses various chlorination practices with HTH in granular and tablet form. Eight tables pertaining to chlorination are included.—Industrial Chemicals Div., Olin Mathieson Chemical Corp.

191*R*

Hypochlorinator—A bulletin describing a Heavy Duty Midget Chlor-O-Feeder as an all purpose, positive displacement, diaphragm pump for fluids such as hypochlorite, pH correctives, and abrasive slurries. The midget delivers 0.5 to 9 gph against pressures up to 85 psig. Bulletin 1201-2.—Proportioneers Inc.

192*R*

Hydro-Classifiers—Bulletin 39-C describes the Hydro classifier design that is similiar to that of the circular clarifier and thickeners with a generally shallower tank and adjustable weir.—Hardinge Co., Inc.

193*R*

Hydrofluosilicic Acid—A brochure on Hydrofluosilicic acid and it's uses for fluoridation by municipalities.—International Minerals & Chemical Corp.

194*R*

Industrial Waste Treatment—Bulletin WC-116 discusses Graver's facilities to handle industrial waste treatment problems.—Graver Water Conditioning Co.

195*R*

Incinerators—Bulletin 111C gives complete information on mechanically stoked incinerators for municipal use.—Morse-Boulger Destructor Co.

196*R*

Incinerators—Bulletin 183 presents incinerators for institutional and industrial wastes.—Morse-Boulger Destructor Co.

197*R*

Incinerators—This attractive bulletin describes and illustrates the C-E incinerator stoker for the incineration of municipal refuse.—Combustion Engineering, Inc.

198*R*

Incinerators—This new bulletin discusses the disposal of sludge, screening, grit and skimmings in a Nichols Herreshoff multiple hearth furnace. Information includes technical data on burning, drying, fly ash removal, ash handling plus an illustrated description of the equipment and its operation.—Nichols Engineering & Research Corp.

199*R*

Industrial Waste Treatment—A booklet describing The Permutit Company's equipment and services for industrial and municipal waste treatment—Permutit Co.

200*R*

Industrial Waste Treatment—Industrial thickeners for blast furnace flue dust washer water clarification, and similar applications are described.—Process Equipment Inc.

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201*R*

Industrial Waste Treatment—Technical Reprint T-145 discusses the problems involved in specifying and selecting industrial waste treatment equipment indicating the types of systems and considerations that must be studied before final selection is made.—Graver Water Conditioning Co.

202*R*

Information System—Bulletin E72-1 explains how dozens of field measurements, made locally and/or remotely, are received and displayed in digital form by the Metrotype Information System. Equipment described may be furnished as part of complete measuring and controlling system or may be used with existing primary measuring devices.—Bailey Meter Company

203*R*

Inserts Venturi Tubes & Nozzles—Bulletin 100 is a 4-page catalog showing types and installation drawings of the Simplex Type TG Tubes and Nozzles.—Simplex Valve & Meter Co.

204*R*

Instrument, Accessories—60-page catalog containing specifications, part numbers and prices on the more than 250 commonly furnished Foxboro instrument parts and supplies.—Foxboro, Co.

205*R*

Instrumentation—A 16-page booklet covering Foxboro instruments manufactured for water and sewage works applications.—Foxboro Co.

206*R*

Instrumentation—Bulletin B96-1 includes detailed description of control systems for all phases of municipal and industrial water treatment processes—Minneapolis-Honeywell Regulator Co.

207*R*

Instrumentation—Data sheets for instrumentation on water and sewage treatment plants; the different types of equipment used and their application.—Fischer & Porter Co.

208*R*

Instruments and Controls—General Bulletin G15-1 describes over one hundred measuring, transmitting, receiving, recording, and indicating instruments and control components. Complete index to product literature is included, plus addresses and phone numbers of all twenty-four district offices.—Bailey Meter Company

209*R*

Instruments, Filter Plant—Bulletins 1002, and 1100 illustrate and describe filter plant gauges and summator equipment.—Simplex Valve & Meter Co.

210*R*

Instruments, Flow Measurement—General catalog 005 presents equipment on meters and gauges for flow measurement.—Simplex Valve & Meter Co.

211*R*

Insulation—Bulletin D-40 gives complete data on NoDrip tape, a cork-filled, water resistant pipe covering that prevents "sweating" or condensation on cold lines.—J. W. Mortell Co.

212*R*

Iron Removal—Technical Reprint T-158 discusses the problem of iron removal for the municipality and presents the proper procedures and methods of study before a plant is designed and installed. This is a very comprehensive discussion of all the technical factors involved in selecting iron removal equipment.—Graver Water Conditioning Co.

213*R*

Joint Cut-In Valves—Specifications, installation illustrations and explanatory text are included in this bulletin on mechanical joint cut-in valves and sleeves.—A. P. Smith Mfg. Co.

214*R*

Jointing Compound—A complete data book on Hydro-Tite, the self-caulking jointing compound for cast iron water mains.—Hydraulic Development Corp.

215*R*

Joints, Rubber—20 page booklet describing Tylox rubber gaskets for leakproof coupling of concrete and vitrified clay sewer pipe—Hamilton Kent Mfg. Co.

216*R*

Joints, Slip—Brochure on Crispin slip joints describing safe, fast way to remove and replace fixtures when repairing lines etc.,—Multiplex Mfg. Co.

217*R*

Lift Stations—Bulletin No. 121 describes in detail the company's UT Packaged Underground Lift Station with Flush-Kleen Sewage pumps—Chicago Pump Co.

218*R*

Lime Slakers—Bulletin 40-E1B covers equipment for lime slaking at 175 to 10,000 lb. per hour with thermostatic water control and vapor removal devices.—Omega Machine Co.

219*R*

Liquid Feeders, Rotodip—Bulletin 65-H12B on a volumetric feeder for liquids, including acids, alkalies, or slurries at rates from 0 to 1800 gallons per hour with repeatable accuracy within ±1%.—Omega Machine Co.

220*R*

Liquid Level Recorder—Bulletin 24 describes a compact, portable, automatic, graphic recorder with a wide variety of interchangeable gage and time scales, particularly adaptable to sewerage studies.—Leupold and Stevens Instruments Inc.

221*R*

Low Pressure Meter—Literature describes a propellor type low pressure line meter for measuring large water volumes in closed conduits.—Sparling Meter Co.

222*R*

Lubricated Swing Gate Valve—Literature describes the "Lubeseal" valve that provides quick, easy, absolutely tight shut-off of flow under high pressure operating conditions—W. S. Rockwell Co.,

223*R*

Magnetic Propeller Drive Meter—Literature describes this main-line meter, incorporating a powerful radial magnet.—Sparling Meter Co.

224*R*

Maintenance of V-Belts—This bulletin contains simple precautions to be exercised to prolong the life of V-belts, to increase drive efficiency and thereby assure full continuous production.—Allis-Chalmers Mfg. Co.

225*R*

Manhole Rings & Covers—This literature describes and illustrates numerous sizes and types for heavy, light, or pedestrian traffic. Top or bottom flanges; cast iron steps.—Clarksville Foundry & Machine Works.

226*R*

Mechanical Joint—A catalog describing different types of pipe and fittings connected with mechanical joints—Alabama Pipe

227*R*

Mechanical Joint—This bulletin illustrates and describes the Clow mechanical joint cast iron pipe.—James B. Clow & Sons, Inc.

228*R*

Mechanical Joint Repair Sleeves—This bulletin describes mechanical joint repair sleeves for repairing cast iron and cement asbestos water main breaks.—Eddy Valve Co.

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229R

Mechanical Jointed Clay Pipe—A 4-page folder describes the new AMVIT jointed vitrified clay pipe, sizes 4 through 24 inches as a true "built-in" mechanical joint ready for immediate, quick and easy installation. The joint is furnished on all standard fittings, as well as pipe, permitting a bottle tight line.—American Vitrified Products Co.

230R

Membrane Filter—Color illustrated booklet details the field and laboratory methods of bacteriological water analysis recently approved by the U. S. P. H. S.—Millipore Filter Corp.

231R

Meter Boxes—Literature illustrates and describes many sizes and types of cast iron meter boxes, and cast iron meter box rims and covers for concrete or tile settings.—Clarksville Foundry & Machine Works.

232R

Meters, Magnetic Water—Bulletin W-811 presents the most important advance in water meter history, the all-new magnetic Rockwell Sealed Register Water Meter. This 24-page bulletin illustrates and describes the principle and design on this new meter. The Sealed Register is available in sizes, ⅝" and ⅝" x ¾"—Rockwell Manufacturing Company

233R

Meter Repair—This complete, well illustrated 16-page manual for the water meter shop tells how to set up a repair and test program, how to lay out the shop, and step-by-step repair instructions.—Neptune Meter Co.

234R

Meter Setting and Testing—Catalog 56 contains complete listing of water meter setting and testing equipment along with information on good meter setting practice under various conditions.—Ford Meter Box Co. Inc.

235R

Meters, Sewage Gas—Bulletin C-5200 describes the company's entire line of sewage gas meters, both large and small capacities.—Rockwell Manufacturing Co.

236R

Meter Testing, Water—A 40-page book on methods and equipment for testing meters, including information on meter shop layout, meter performance, and a bibliography on meter maintenance.—Ford Meter Box Co., Inc.

237R

Meters, Water—Catalog gives full details of American disc type water meters, both frost bottom and solid casing types, sizes ⅝ to 6 inches.—Buffalo Meter Co.

238R

Meters, Water—Direct reading propeller type units for metering water and other free-flowing, non-corrosive liquids are described in this bulletin.—Omega Machine Co.

239R

Meters, Water—This catalog gives details and specifications of Trident meters from ⅝ to 16" in size. Frostproof and split-case meters for household use, style 3 meters for intermediate flows, and larger compound, crest and Protectus fire service meters are also covered.—Neptune Meter Co.

240R

Microstraining—A series of folders on test results and operating data illustrating the Microstraining process. Economic removal of microscopic debris and plankton render this method of automatic filtration invaluable in water treatment, pollution prevention, conservation & water re-use problems.—Glenfield and Kennedy, Inc.

241R

Mixflo Pumps—A 16-page bulletin on mixflo pumps for irrigation, drainage, sewage disposal, condenser circulating and low water supply. Performance curves and drawings are also included.—Worthington Corp.

242R

Mixing—Bulletin #5782 illustrates and describes the "FM" liquid mixers with tables and application recommendations.—General Filter Co.

243R

Modern Sewage Treatment—This 12-page bulletin describes the distinguishing characteristics, types, sizes, applications and operation of major Dorr-Oliver sewage treatment equipment and presents a number of typical plant flowsheets. Also included are photographs and line and wash drawings of various units.—Dorr-Oliver Inc.

244R

Moisture-Matic Balance—Bulletin describes motor-driven torsion balance automatically weights sample after test and preserves moisture result directly in per cent on a counter. I-R moisture matic balance may be used for any material that can be safely dried by heat—American Hospital Supply Co.

245R

Monorake—This 12-page bulletin presents the Dorrco Monorake. It describes the design, types and sizes, operation and advantages of this mechanism for cleaning rectangular sedimentation basins and tabulates actual maintenance costs from a number of installations.—Dorr-Oliver Inc.

246R

Motor, Explosion-Proof—Literature describes a new line of totally enclosed, explosion proof motors.—Fairbanks, Morse & Co.

247R

Motors—Construction features of large end-shield bearing synchronous motors are described in this bulletin.—Allis-Chalmers Mfg. Co.

248R

Motors—The "Synduction" motor, a synchronous induction machine which provides dependable constant speed, simplicity of operation and low first cost in a variety of applications requiring 40 hp and below is described in this bulletin.—Allis-Chalmers Mfg. Co.

249R

Municipal Castings—Booklet showing manhole rings and covers, coal hole rings and covers, manhole steps, catch basins, valve boxes, drain pipe, and drainage or inlet grates, with or without frames.—Clarksville Foundry & Machine Works.

250R

Municipal Water Conditioning—This general bulletin discusses the various types of equipment available from the company to handle municipal water problems.—Graver Water Conditioning Co.

251R

Odor Control—A bulletin describing Cloroben. A sanitation chemical that provides control of sewage odors in treatment plants, septic tanks, cesspools and chemical toilets.—Cloroben Chemical Corp.

252R

Odor Control—Technical Data Sheet provides information on Cifon, which controls odor in sanitation disposal, sewage disposal plants in the raw, sludge storage tank; for grit disposal, sand filter beds; effluent—Fine Organics, Inc.

253R

Ovaloid Storage Tanks—A brochure, "Cole Ovaloid Tanks" gives photographs and table of capacities, size and necessary foundation space of full self-supporting bottom tanks with low head range.—R. D. Cole Manufacturing Co.

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254R

Package Treatment Plant—Folder describes the Comple-Treator, a self-contained complete waste treatment facilities for small plants.—Dorr Oliver, Inc.

255R

Parabolic Flume—Bulletin 801 is an 8-page catalog on the Simplex "S" Flume showing typical installations and descriptive matter concerning dimensions and capacities of this type of parabolic flume.—Simplex Valve & Meter Co.,

256R

Peri-Filter System—A bulletin on the Dorrco Aldrich Peri-Filter System comprised of a Dorr-Oliver pre-treatment unit and an annular rapid sand filter combined in a single unit. Economic advantages for either municipal or industrial users are discussed.—Dorr-Oliver Inc.

257R

pH and Chlorine Control—This handbook gives theory and applications of pH and chlorine control and describes the complete line of Taylor comparators for water and sewage analysis.—W. A. Taylor & Co.

258R

pH Control—This bulletin discusses the use of PH-Plus (½-lb. cakes of fused sodium carbonate) in pH control of swimming pool water and in general industrial water treatment. Covered in detail are various types of feeding equipment in which these slow-dissolving cakes of fused alkali will provide positive and economical alkalinity control.—Industrial Chemicals Div., Olin Mathieson Chemical Corp.

259R

Photoelectric Colorimeter—2—color, 16-page booklet describes the Klett-Summerson photoelectric colorimeter and gives operating instructions.—Klett Mfg. Co.

260R

Pipe, Ball Joint—A catalog containing instructions, for assembly, weight and dimension tables and different methods of installing the ball joint pipe for river crossings and submarine service —American Cast Iron Pipe Co.

261R

Pipe Clay—Presents the complete story on clay pipe—National Clay Pipe Mfgr. Inc.

262R

Pipe Cutter—A catalog sheet giving details on Models 6 and 12 pipe cutters for cutting cast iron, Duriron, vitreous clay water pipe and cement sewer tile. A parts and price list is also included. —Spring Load Manufacturing Corp.

263R

Pipe Cutters—Catalog No. 40 gives descriptive information on Ellis Pipe Cutters for cutting Cast Iron or Steel Pipe in sizes from 4 to 12 inches.—Ellis & Ford Mfg. Co.

264R

Pipe Cutting & Jointing Tools—A catalog sheet containing information on the Spring Load Machining and Tapering tool, for asbestos cement pipe. Catalog discusses machining pipe ends for: Ring-Tite couplings; simplex couplings; poured flange assembly; tapered couplings; making closures; and end facing.—Spring Load Manufacturing Corp.

265R

Pipe Laying & Jointing Tools & Equipment—A complete general catalog showing the line of equipment for water, sewer and gas lines.—Joseph G. Pollard Co., Inc.

266R

Pipe, Plastic—8-page booklet includes complete tables on pressure drop through plastic pipe, pressure-temperature ratings for different sizes, and recommended pumping depths.—Crane Co.

267R

Pipe Reinforced Epoxy—Technical data sheet on Bondstrand-manufactured of interwoven fiber glass filaments impregnated with epoxy resins, heat cured. Corrosion resistant to meet pipe, ducting and tubing needs. Nontoxic, nonflammable and collapse resistant—Amercoat Corp.

268R

Pitot Equipment—Bulletin 1301 is an 18-page catalog which describes and furnishes instructions for Simplex Equipment. This bulletin also covers the theory, Formulae, notations, tables and curves for use of the pitot recorders.—Simplex Valve & Meter Company

269R

Plastic Coatings—This 32-page handbook gives complete general and technical data on condensation and how NoDrip plastic coating controls it.—J. W. Mortell Co.

270R

Pneumatic Controller—12 page Catalog 53P-4000 discusses motion-balance pneumatic controllers with exclusive regenerative feedback circuit.—Fischer & Porter Co.

271R

Pneumatic Transmitter—Bulletin 285-L2B describes the BalanCel transmitter as a simple force-balance device for transmission of flow, level, and pressure data. Also for the summation, averaging, etc., of two quantities.—Builders-Providence, Inc.

272R

Pool Sanitation—42-page booklet discusses in detail the safe treating of swimming pool water with HTH. Describes the various methods and advantages of disinfecting water with calcium hypochlorite as opposed to other means of chlorination.—Industrial Chemicals Div., Olin Mathieson Chemical Corp.

273R

Porous Media—Bulletin describes use of porous ceramic plates and tubes in a wide variety of equipment used in the treatment of water, sewage and industrial wastes. Charts and tables help provide data required in operating units equipped with these porous media.—The Carborundum Co.

274R

Pressure Filters—This bulletin describes the company's line of horizontal and vertical sand and gravel pressure filters. Cut-away views and sizing tables are included.—Graver Water Conditioning Co.

275R

Pressure Pipe, Asbestos Cement—An 8-page, 2-color folder featuring Transite asbestos-cement Pressure Pipe, its manufacture, properties and advantages. The folder also shows how, in combination with the Ring-Tite coupling, to install water lines faster to last longer. Various installation photos are included. —Johns-Manville Corp.

276R

Prestressed Concrete Tanks—Bulletin T-15. A 4-page bulletin on the design and use of prestressed concrete tanks for water supply, sewage treatment, processing applications and containment vessels.—The Preload Company, Inc.

277R

Primary Elements—A 16-page Primary Elements Catalog which contains listings and data of all forms of primary elements, includes information on orifice plates, flow nozzles, forged and fabricated, and Venturi tubes, cat cast and fabricated and their accessories—Penn Instruments Div., Burgess-Manning Co.

278R

Process Package Plants—Bulletin discusses the small package sewage treatment plant that combines aeration, reaeration, settling and aerobic sludge treatment—Walker Process Equipment, Inc.

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279*R*

Proportioning Pump—Bulletin 1260-2 describes an automatic and proportioning chemical feeder, the Chem-O-Feeder which utilizes water from the main itself and which will feed disinfecting solution in proportion to variable flow in the main.—Proportioneers, Inc.

280*R*

Pump Control—Bulletin describes a stepless variable speed flow control for sewage and water pumps. Design construction and operating costs savings and advantages of the Flomatcher system (wound rotor motor and water rheostat) are discussed. Includes pictures of typical installations.—General Services Co.

281*R*

Pump Controllers—This bulletin describes purged air and static pump controllers, and gives the different applications for each type. Controllers are suitable for both sewage and clear water.—Healy-Ruff Company.

282*R*

Pumping Stations—"The Application and Design of Prefabricated Pumping Stations" is a manual containing general design information, specifications, drawings and pictures of the Z-F Prefabricated Pumping Station.—Zimmer & Francescon

283*R*

Pump, Sanitation, Solids—This bulletin describes the Wemco Torque flow solids pump and presents three typical sanitation transfer problems. Included are tabulations of general specifications for each service.—Western Machinery Co.

284*R*

Pump, Solids—This bulletin brings up-to-date dimensions and capacity information on the Wemco Torque Flow solids pump. A cutaway photographs and diagrammatic sketch illustrate the new pumping principle which eliminates clogging.—Western Machinery Co.

285*R*

Pump, Sump—Bulletin SP-58 describes a self-contained air motor driven portable sump pump for removing clean or dirty water, sewage or sludge from cellars, excavations, ditches, trenches and settling basins.—Schramm, Inc.

286*R*

Pumps—A series of 4 bulletins cover the complete line of "American" double-suction, split-case, single-stage, two-stage, end suction, axial flow, sludge and deep well turbine pumps.—American Well Works.

287*R*

Pumps, Axial and Mixed Flow—Bulletin G-100 includes construction and design details, typical installations, and suggested station arrangements. Bulletin F-102 covers Mixed Flow Volute Type pumps.—C. H. Wheeler Mfg. Co., Economy Pump Div.

288*R*

Pumps, Centrifugal—A complete 16-page booklet presenting the entire Weinman line. An illustration of each pump is given together with recommended uses. A cross reference on type of application and pump selection is also presented. Ratings on head and gallons per minute are listed for each of the twenty different types of pumps as well as motor R.P.M. alternate choices. Individual bulletins supplying more detailed data as to performance curves, dimensions, mechanical construction and features are available on request and listed in the complete line folder, —Weinman Pump Mfg. Co.,

289*R*

Pumps, Deep Well Vertical Turbine—This bulletin, in color, shows a cross-section of the Layne Vertical Turbine pump and applications for it. Both the water and oil lubricated pump bulletins available.—Layne & Bowler, Inc.

290*R*

Pumps, Freflo—A 12 page bulletin covering horizontal and vertical Freflo pumps for handling sewage and industrial wastes. It contains rating curves for 18 pump models. Also included are charts for selection of shafting for use with vertical pumps. Complete dimension data are given for all pump models. —Worthington Corp.

291*R*

Pumps, High Head—Bulletin A-155 describes and illustrates horizontally split case double suction pumps for medium and high head service. Cross Section drawings and construction details are included.—C. H. Wheeler Mfg. Co., Economy Pump Div.

292*R*

Pumps, Sewage and Sludge—Bulletin No. KSP-2 a 4 page, 2 color description of Komline-Sanderson dual-valve plunger and diagram pumps, with illustrations and plunger pump selection chart. —Komline Sanderson Engineering Corp.

293*R*

Pumps, Sewage and Sludge—The company has a series of bulletins giving data, design features, and specification information on sewage and sludge pumps.—Chicago Pump Co.

294*R*

Pumps, Submersible—A 12-page bulletin describes the line of BJ Submersibles and lists their advantages. Safety features, special applications, specifications and selection chart are included. A list of typical municipal and industrial users are given along with a list of the sales and service offices.—Byron Jackson, Div. of Borg-Warner Corp.

295*R*

Rate Controllers—Bulletins 600-G6A and 600-J9A on filter effluent or back wash rate controllers.—Builders-Providence, Inc.

296*R*

Recarbonation—Bulletins 1300 and 1310 outline the story of recarbonation and its use in stabilizing lime-softened waters.—Infilco Incorporated

297*R*

Receiver-Recorder & Controller—Product specification E12-5 illustrates how four pneumatically transmitted variables may be continuously recorded, in any combination, in the same case by use of plug-in receivers and controllers. Sealed capillary inking system operates for one year without refilling.—Bailey Meter Company

298*R*

Regulators, Sewage Gas—This bulletin presents data on Rockwell's complete line of sewage gas regulators, with inlet pressures above and below 5 psi.—Rockwell Manufacturing Co.

299*R*

Ring-Tite Fire-Hydrants—This bulletin illustrates and describes the line of fire hydrants and gate valves with Ring-tite connecting joints made by the company. A. P. Smith Mfg. Co.

300*R*

Rotary Distributors—Bulletin #5452 gives a brief description of the new, non-clogging, sealess, "Gard" rotary distributor for trickling filters.—General Filter Co.

301*R*

Rotary Sludge Dryers—This 4-page bulletin discusses and illustrates the Standard Hersey drying system for odor free sewage-sludge drying. Keyed photographs explain construction features.—Standard Steel Corp.

302*R*

Salt—This booklet illustrates the various types of salt available for use in the Zeolite water softening process.—Morton Salt Co.

303*R*

Samplers—This brochure illustrates and describes in detail the company's Tru-Test Sampler.—Chicago Pump Co.

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304*R*

Screening Equipment—Booklet 2587 illustrates and discusses Link-Belt's line of screening equipment for water, sewage and industrial waste. Dimension drawings and specifications are included.—Link-Belt Co.

305*R*

Screening Equipment—This technical bulletin describes mechanically cleaned bar screen and grinder designed for a wide range of channel widths and settings with grinder attached to sorting tray, returning shredded screenings to sewage flow.—American Well Works.

306*R*

Self-Priming Pumps—Folder L-509A presents complete descriptions and specifications of self-priming, gasoline-engine-driven, centrifugal and diaphragm pumps.—Homelite, Div. of Textron Inc.

307*R*

Sewage Ejector—A series of engineering tables provide a simplified method of selecting clog-proof "Flush Kleen" sewage ejectors. Examples are given for determining the inflow, discharge heads and type of ejector to use.—Chicago Pump Co.

308*R*

Sewage Ejector Pneumatic—Catalog No. KSM-2, a 14 page, 2 color brochure, complete with illustrations, layout diaphragms, dimension tables, compressor motor selection tables and description of the Komline-Sanderson Pneumatic Sewage Ejector Systems. Covers simplex and duplex units, pneumatically and electrode controlled.—Komline-Sanderson Engineering Corp.

309*R*

Sewage Ejector System, Pneumatic—12-page 2 color booklet describes the Blackburn-Smith Pneumatic Sewage Ejector that can be operated by either a mechanical float and electric float switch, a mechanical float and pneumatically controlled air valves, or electrode controls. Performance charts photographs and installation diagrams are also included.—Blackburn-Smith Mfg. Co., Inc.

310*R*

Sewage Lift Stations—A 100-page Engineering Data Manual on factory-built sewage lift stations. Contains design notes, selection charts, drawings and specifications on stations of from 30 to 4500 GPM.—Smith & Loveless, Inc.

311*R*

Sewage Jointing—Three folders discuss and illustrate how unusual joint sealing problems were solved at different locations including 25-mile, 18-mile and 92-mile sewer projects.—Presstite-Keystone Engineering Products Co.

312*R*

Sewage Treatment—Bulletin 6041, Dorr-Oliver Equipment and Methods for Modern Sewage Treatment, describes briefly major components of Dorr-Oliver equipment available for primary through complete sewage treatment.—Dorr-Oliver Inc.

313*R*

Sewage Treatment Equipment—4 page bulletin describes the design, operation and advantages of the Spiro Vortex system for the complete treatment of sewage.—Dorr-Oliver Inc.

314*R*

Sewage Treatment—A 16-page Engineering Data Manual on factory-built Sewage Treatment Plants. Contains design note, selection charts, drawings and specification on plants with capacities up to 14,000 G. P. D.—Smith & Loveless, Inc.

315*R*

Sewage Treatment—A 64-page catalog covering Jeffrey equipment for the treatment of sewage, water and industrial waste. It is profusely illustrated with installation views and line drawings.—The Jeffrey Mfg. Co.

316*R*

Sewage Treatment—A series of 6 bulletins gives detailed information on equipment to perform various steps in sewage treatment. Collectors for solids removal, screens, grit removal units, rotary distributors and digester sludge heating units are covered.—Walker Process Equipment Inc.

317*R*

Sewage and Waste Treatment—Bulletin No. 300 is a general catalog of equipment and methods for modern waste treatment—Pacific Flush Tank Co.

318*R*

Sewage and Waste Treatment—Brochure 135 describes in detail Chicago Pump's Ratedaeration Sewage Treatment process to serve 50 to 50,000 people.—Chicago Pump Co.

319*R*

Sewer Cleaning—Attractive new brochure describes modern techniques and equipment used in the cleaning and complete restoration of clogged sewers of any size or location. Complete contracting service and various methods used to effect maximum pipe efficiency are graphically illustrated.—Nation Power Rodding Corp.

320*R*

Sewer Cleaning Equipment—48 page catalog 55-A describes tools for cleaning and removing every kind of sewer deposit. Every thing from low budget equipment, operated by hand to fully self-contained and automatic equipment such as the Seweroder and Truck-Loder Bucket Machine is offered. A section of the catalog is also devoted to equipment for cleaning water mains.—Flexible Inc.

321*R*

Sewer Lining, Plastic—This bulletin describes T-Lock Amer-Plate, a continuous plastic sewer lining to prevent hydrogen sulfide corrosion. It shows how the T-shaped ribs lock the sheet into the pipe when the concrete is poured.—Amercoat Corp.

322*R*

Sewer Pipe, Clay—Catalog SE-50 gives a complete summary of shapes and sizes of clay sewer pipe and supplementary clay products.—Natco Corp.

323*R*

Sewer Pipe, Asbestos Cement—An 8-page, 2-color folder featuring Transite asbestos-cement sewer pipe, lists its advantages, and how it, with the Ring-Tite coupling makes possible tight sewer systems at low installation cost.—Johns-Manville Corp.

324*R*

Sewer Sealing System—"3 Steps to Tighter Sewer Joints" is a 20-page booklet on the Presstite Sealing System. The three steps, specifications, and actual installation photographs are also included.—Presstite-Keystone Engineering Products Co.

325*R*

Sewer Valves—Brochure covering construction and operation of Crispin Sewer Valves designed to eliminate and control air in sewage force mains.—Multiplex Mfg. Co.

326*R*

Silica (Activated) Feeder—Catalog 60.110 gives description, design features, operating instructions and technical information on the series A-637 WT Silactor, a device for the continuous production and application of chlorine activated silica.—Wallace & Tiernan, Inc.

327*R*

Silica Activator and Feeder—Bulletin 63-M1 describes equipment designed for the continuous activation and feeding of sodium silicate. The unit features sequence starting, automatic rinse, antigel interlock and variation of aging concentration and aging time.—Omega Machine Co.

328*R*

Single Stage Centrifugal Pumps—This 4-page bulletin discusses the single stage

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volute pumps for water works, circulation, drainage and general service.—Worthington Corp.

329*R*

Siphons for Sand Filters—This bulletin provides curves for determining rates of siphons discharging into open troughs. Sand filter design for smaller plants is discussed along with piping layouts for the types of siphons available.—Pacific Flush Tank Co.

330*R*

Sleeves and Valves, Cutting-In—It is easy to install more valves on existing pipe lines, for better control, by using these Mechanical Joint Cutting-In Sleeves and Valves. Suggestions on how to install. Circular No. 20.—M&H Valve and Fittings Company.

331*R*

Sleeves and Valves, Tapping—Four page illustrated circular describes how to tap water mains under pressure with special tapping sleeve and tapping valve. Made for use on pipe from 4" to 16" diameter. Folder No. 12.—M&H Valve and Fittings Company.

332*R*

Sludge Collectors—Bulletin 315-61 highlights Rex conveyor sludge collectors and appurtenances. Information is general in nature, and is intended primarily to illustrate the diversity and quality of these collectors.—Chain Belt Co.

333*R*

Sludge Digestion—Bulletin 6262 describes the Dorrco Densludge Process consisting of a grit washer, thickener, digester and spiral heat exchanger.—Dorr-Oliver Inc.

334*R*

Sludge Digestion—Bulletin 35-D describes digester that prevents scum accumulation and insures uniform gas production.—Hardinge Company, Incorporated.

335*R*

Sludge Digestion—Bulletin 6591 presents the Dorr type MA digester which incorporates, single stage digestion, high capacity mixing and gas storage in a single unit.—Dorr-Oliver Inc.

336*R*

Sludge Digestion Tanks—Bulletin T-20. A two page Bulletin on prestressed concrete tanks for sludge digestion, clarifiers, flocculators and thickeners.—The Preload Company, Inc.

337*R*

Sludge Digestion—In addition to bulletins 332 and 235 on floating covers and sludge heat exchangers, P. F. T. has available bulletins 236 and 137 covering floating cover position indicators and gauge boards.—Pacific Flush Tank Co.

338*R*

Sludge Disintegrator—Literature describes the increasing popularity of sewage sludge as a soil conditioner.—Royer Foundry & Machine Co.

339*R*

Sludge Drying and Incineration—Bulletin FD-57 covers the C-E Raymond System of Sludge Drying and Incineration. It briefly outlines the problem of sewage disposal and shows why heat drying is regarded as an ideal solution. Diagrams and photographs are also included.—Combustion Engineering Inc.

340*R*

Sludge Removal—Bulletin 253B describes "American" positive flight conveyors, circular clarifiers, and sludge control valves.—American Well Works.

341*R*

Sludge Removal—Rex Unitube Tow-Bro for removal of light, tricky sludges is covered in this bulletin. New, improved header design is introduced.—Chain Belt Co.

342*R*

Slurry Feeder—This catalog briefly describes the design, operation and application of this positive displacement slurry pump for feeding lime, diatomaceous earth and similar slurries.—Precision Chemical Pump Corp.

343*R*

Spherical Storage Tanks—A Brochure, "Cole Spherical Tanks on Tubular Towers". Photographs of installations, table of capacities and sizes, of spherical steel tanks on tubular towers.—R. D. Cole Manufacturing Co.

344*R*

Spiractor—Bulletin (2384) presents the Permutit Spiractor for softening and alkalinity reduction. This compact cold lime-soda softener is recommended for the treatment of clear, hard water. The Spiractor is small in size and flexible in operation. No sludge handling necessary.—Permutit Co.

345*R*

Square Bottom Valve—This bulletin gives complete descriptive information on the Rensselaer square bottom valve.—Ludlow Valve Mfg. Co., Inc.

346*R*

Standard Sewage Siphons—This bulletin describes the P. F. T. standard sewage siphon for small disposal plants for use with small sand filters, sub-surface tile fields and either septic tanks or small Imhoff tanks. Standard dimensions and capacity of siphons are included.—Pacific Flush Tank Co.

347*R*

Steam Cleaner—Booklet discusses the Hypressure Jenny steam cleaner for cleaning and deodorizing bar screens, grit and scum loading pits, etc.—Homestead Valve Mfg. Co.

348*R*

Steel and Alloy Structures—This 4-page folder outlines briefly the many services to industry provided by Graver-built steel and alloy structures, both smaller shop-built vessels and large field-erected installations.—Graver Tank & Mfg. Co., Inc.

349*R*

Steel Pipe—A series of four booklets illustrates and discusses the applications of steel pipe as a 14-ft. 8-in. diameter welded steel flow line, 42-in. diameter tar-enameled for water supply, a 72-in. force main and the fabrication of a 96-in. steel pipe and its installation.—Bethlehem Steel Co.

350*R*

Steel Pipe—Booklet 402 describes the construction of a 72-inch Ramapo force main for the North Jersey Water Commission. Booklet 408 covers the construction of a 37,000-ft. Northwest pumping main at Reading, Pa. The Welded Steel Pipe booklet describes the fabrication of a 96-inch steel pipe and its installation at Sparrows Point, Md.—Bethlehem Steel Co.

351*R*

Steel Reservoirs and Standpipes—A 24-page booklet on Horton Steel Reservoirs and Standpipes. Illustrations show

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installations from 50,000 to 10,000,000 gal. capacity with cone, umbrella, or ellipsoidal roofs and ornamental structures with special architectural features. Also included are: table of standard capacities, information on foundations, advantage of pickling and painting, and data on the use of suction tank for fire protection.—Chicago Bridge & Iron Co.

352R

Steel Reservoirs and Standpipes—A brochure on flat bottom water storage that discusses the uses of steel tanks with photos showing various roof types, ornamental structural features, and various sizes. A list of standard reservoir dimensions is also included.—Pittsburgh-Des Moines Steel Co.

353R

Storage Tanks—This 20-page booklet covers the many uses of standard storage tanks. Cone roof tanks serving as storage units at innumerable industrial and municipal installations are shown. —Graver Tank & Mfg. Co., Inc.

354R

Strainers, Liquid—Bulletin describes the company's line of self-cleaning liquid strainers.—Golden-Anderson Valve Specialty Co.

355R

Surge and Hammer Control—Bulletin 200 illustrates and describes the company's Controlled Closing air valve that was designed for the protection of pipe lines against surge built-up pressures or water hammer.—Simplex Valve & Meter Co.

356R

Surge & Water Hammer Control—A 28 page booklet describing the construction of Crispin automatic air valves available for control of air problems in lines handling liquids.—Multiplex, Mfg. Co.

357R

Squirrel-Cage Motors—This bulletin describes the company's large two-pole squirrel-cage induction motors, 900 hp and larger, designed to meet requirements of today's high speed drives.—Allis-Chalmers Mfg. Co.

358R

Supervisory and Remote Control—Bulletin 240-P2A describes unlimited number of control or advisory functions from central control panel over widely spread system using sequencing transmission system. Other bulletins describe Chronoflo telemetering, "Synchro-Scan" pneumatic and electrical transmission and control of level, pressure, pumps, etc.—Builders Providence, Inc.

359R

Swimming Pool Chemicals—This catalog gives complete data, prices, descriptions and usage of chemicals for water treatment of swimming pools, lakes and reservoirs.—Modern Swimming Pool Co., Inc.

360R

Swimming Pool Equipment—Bulletin (2157) outlines purification and recirculation equipment necessary for the modern pool. Tables are provided for correctly sizing equipment and pools.—Permutit Co.

361R

Swimming Pool Equipment—The bulletin describes various types of purification and recirculation equipment. Details of equipment design, pool sizes and general sizing tables for equipment and pools are included.—Graver Water Conditioning Co.

362R

Swimming Pool Equipment—This 52-page catalog, profusely illustrated, contains data, photographs and prices of every item needed to build a new pool, or to equip and maintain an existing pool.—Modern Swimming Pool Co., Inc.

363R

Swimming Pool Overflow Gutter—Bulletin 6W-OG illustrates the efficient use of Natco Ceramic Glaze Swimming Pools Non-Slip Overflow Gutter and Glazed Tile for indoor pools.—Natco Corp.

364R

Swing Type Check Valves—Iron body, bronze mounted check valves with lever and weight, lever and spring, or plain. Furnished in sizes 2"-24". Circular No. 10.—M&H Valve and Fittings Co.

365R

Swing-Type Check Valves—This bulletin illustrates and describes the Rensselaer swing type check valves and the clear way, quiet closing check valve.—Ludlow Valve Mfg. Co., Inc.

366R

Tapping Machines—The S-54 tapping drilling machine, in size range 2 to 12 inches inclusive are illustrated and described in this bulletin.—A. P. Smith Mfg. Co.

367R

Tapping Sleeves—Bulletin D illustrates and describes Rensselaer tapping sleeves and valve.—Ludlow Valve Mfg. Co., Inc.

368R

Tapping Sleeves—This bulletin describes and illustrates the complete line of mechanical joint tapping sleeves and valves manufactured by the company. —A. P. Smith Mfg. Co.

369R

Tanks, Water—4 page folder illustrates and presents related data on steel water tanks—Graver Tank & Mfg. Co., Inc.

370R

Tapping Valves & Sleeves—This bulletin illustrates and describes Iowa tapping valves and sleeves, and repair sleeves for water mains.—Iowa Valve Co.

371R

Tapping Valves & Sleeves Under Pressure—This bulletin describes the Eddy tapping valves and sleeves, for tapping water mains under pressure.—Eddy Valve Co.

372R

Taste and Odor Control—This booklet describes the use of Aqua Nuchar activated carbon in water purification.—West Virginia Pulp & Paper Co.

373R

Telemetering—Transmission and reception of data on flow, liquid level, pressure, temperature, etc., from any distance over a single two-wire circuit is shown in this bulletin.—Builders-Providence, Inc.

374R

Thickeners—Bulletin 31-E describes the "Auto-Raise" thickener mechanism for both small and large heavy duty settling tank operations, and waste treatment applications of the rectangular type clarifier.—Hardinge Company, Incorporated.

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375R

T-Lock Amer-Plate—This brochure describes T-Lock Amer-Plate, a continuous plastic sewer lining. "T-Lock" refers to the T-shaped ribs which project from the back of the sheet and lock the sheet into the pipe or structure when the concrete is cast.—Amercoat Corporation.

376R

Trash Racks—Bulletin No. 158 describes the Leonard Trash Rack Rakes with dimensions, specifications, and typical arrangements.—S. Morgan Smith Co.

377R

Trenchers and Backfillers—A 2-color booklet describing the features and listing specifications of the models 92 and 95 "Baby Diggers," the models 110, 140, 240, and 320 standard trenchers, and models 80W and 190 backfillers. Photographs of each piece of equipment are shown along with illustrations of the equipment in operation.—Cleveland Trencher Co.

378R

Trenching & Construction Equipment—Thirteen bulletins on tractors, crawlers, trenchers and loaders for installation of water mains or sewers.—Oliver Corp.

379R

Trickling Filter Distributor—This bulletin describes the Dorrco Distributor, a self-propelled rotary unit for low and high rate trickling filters.—Dorr-Oliver Inc.

380R

Trickling Filters Distributor—Bulletin 313A covers spreader jets for rotary distributors for trickling filters.—Pacific Flush Tank Co.

381R

Trickling Filter Distributor—This bulletin describes the "Sy-No-Seal" reaction type rotary distributor which contains no seal between the stationary center column and the rotating distribution arms.—Smith & Loveless, Inc.

382R

Trickling Filter Distributor—This technical bulletin describes reaction and positive drive types, equipped with patented dual oil seal which will withstand at least 10' of water pressures.—American Well Works.

383R

Tyton Joint Pipe—This booklet presents the U. S. centrifugally cast "Tyton joint" pipe for water and sewage. This new joint pipe is simple, sturdy and tight. Illustrations show details of joint and method of assembly.— U. S. Pipe & Foundry Co.

384R

Untreated Sewage, A Community Menace—A four-page booklet for use by municipalities in promoting the construction of sewage treatment plant by pointing out the effects of pollution and benefits from sewage treatment. Included is a sketch and explanation of how a typical sewage treatment plant works.—Portland Cement Association

385R

Upflow Clarifier—Bulletin 6W46 describes clariflow unit, a vertical rise clarification unit for circular, square and rectangular tanks.—Walker Process Equip. Inc.

386R

Upflow Coagulation Unit—This bulletin describes the operation advantages and design features of the Permutit Precipitator and contains flow diagrams, installation photos and specifications.—The Permutit Co.

387R

Vacuum Breakers—Brochure on Crispin air and vacuum valves designed to break the vacuum during the emptying operation of a pipe line or tank.—Multiplex Mfg. Co.

388R

Vacuum Filter—16 page brochure on the Coil-filter, the sludge vacuum filter featuring permanent type filter media, non-clogging operation, constant output. Standard sizes of equipment are listed. Bulletin No. 106—Komline Sanderson Engineering Corp.

389R

V-Belt Drives—A 44-page booklet carrying handy multi-color tables for quick and easy selection of variable speed "Texrope" drives.—Allis-Chalmers Mfg. Co.

390R

V-Belts—Construction features of the "Texrope" grommet V-belt which provides 20 to 50 percent longer life than ordinary belts are described in this bulletin.—Allis-Chalmers Mfg. Co.

391R

Valve and Meter Boxes—Bulletin 2000 on Valve, Roadway, Service and Meter Boxes along with Manhole Frames and Covers.—Alabama Pipe Co.

392R

Valve Butterfly—This 2-color brochure describes Leopold rubber seated butterfly valves. Complete details on the construction features and valve assembly are included.—F. B. Leopold Co., Inc.

393R

Valves, Ball—New ACF Non-lubricated ball valves are completely described in catalog 1000. Valves available in semi-steel and carbon steel with full-bore conduit, leakproof, two-way seal and other outstanding features.—W-K-M division of ACF Industries, Inc.

394R

Valve Box Locator—This bulletin discusses and illustrates this small, rugged easy-to-use instrument, that operates without batteries, wires or switches, for locating water or gas valve boxes buried under earth, blacktop, ice or snow.—Aqua Survey & Instrument Co.

395R

Valve Operators—Product Specification P8101 shows how the regulation of fluid flow may be improved by use of a characterized valve operator. Butterfly valves, feeders, and other final control elements may be operated on a straight-line flow basis—Bailey Meter Company.

396R

Valve Plug—Literature describes plug valve with a facing of Hycar American Rubber—DeZurik Corp.

397R

Valves—A folder discussing bronze and iron valves, gate, globe, angle, check and meter valves, sluice gates, pivot valves and motor unit.—Chapman Valve Manufacturing Co.

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398*R*

Valves, Air Release—A 28 page catalog offering complete information on the many types of Crispin automatic air valves preferred by works engineers for over 45 years for positive air control. Multiplex Mfg. Co.

399*R*

Valves & Hydrants—Catalog 52 describes and illustrates complete line of gate valves, hydrants, pipe fittings, and accessories for construction of water works systems, sewage plants, filter plants and industrial uses.—M & H Valve & Fittings Co.

400*R*

Valves, Altitude and Level—Bulletin W-4-A describes altitude valves and modifications of water level control valves.—Golden-Anderson Valve Specialty Co.

401*R*

Valves and Hydrants—Circular 49 is a listing of a complete line of gate valves and hydrants with mechanical joint ends.—M & H Valve and Fittings Co.

402*R*

Valves, AWWA—Four page illustrated circular describing A.W.W.A. Gate Valves, Class C, NRS or OS & Y. These are double disc gate valves with conventional packing or O-ring seal plate, in sizes 2"-36". Circular No. 14—M & H Valve and Fittings Co.

403*R*

Valves, Brass—Folder on brass composition-disc globe, mangle and lift check valves.—Crane Co.

404*R*

Valves, Butterfly—A manual on rubber seated butterfly valves containing complete information including data on valve sizing, operator selection, theory of valve design, etc.—Henry Pratt Co. Inc.

405*R*

Valves, Butterfly—Bulletin 650-L1B on tight-closing rubber seated butterfly valves built to AWWA specifications.—Builders-Providence, Inc.

406*R*

Valves-Butterfly—Bulletin No. 5708 gives complete description of the Darling-Pelton Rubber Seated Butterfly Valves.—Darling Valve & Mfg. Co.

407*R*

Valves, Butterfly—This bulletin covers a new series of butterfly valves designed primarily for municipal water supply or disposal systems.—Allis-Chalmers Mfg. Co.

408*R*

Valves, Check—Bulletin #W-1 illustrates and describes cushioned type swing check valves.—Golden-Anderson Valve Specialty Co.

409*R*

Valves, Cut-in—A 4-page bulletin tells how these cushioned emergency cut-in valves automatically open to emergency water supply.—Golden-Anderson Valve Specialty Co.

410*R*

Valves, Cushioned—Bulletin describes the company's cushioned valves in action.—Golden-Anderson Valve Specialty Co.

411*R*

Valves, Diaphragm—8-page Bulletin gives complete information on the Grinnell-Saunders diaphragm valve.—Grinnell Co. Inc.

412*R*

Valves, Gate—Manual, electric motor, and hydraulic cylinder operated gate valves, in sizes 2 to 66 inches, are illustrated and described in this bulletin.—A. P. Smith Mfg. Co.

413*R*

Valves, Lubricated Plug—This bulletin describes and illustrates the utility of the Rockwell-Nordstrom lubricant-sealed plug valves in sewage treatment plants.—Rockwell Manufacturing Co.

414*R*

Valves, Plug—Book 39-2 describes cam-sealed quarter-turn plug valves. Book 39-3 shows lever-sealed quarter-turn plug valves with built-in means of moving plug under all conditions. Book 39-5 describes lubricated plug valves in straightway, 3-way, 4-way and multiple port types.—Homestead Valve Mfg. Co.

415*R*

Valves, Plug—Catalog 1100 covers ACF carbon steel lubricated plug valves, ASA 150 and ASA 300, including straightway, venturi and multiport types.—W-K-M division of ACF Industries, Inc.

416*R*

Valves, Plug—This 36-page catalog contains the complete line of plug valves, discussing eccentric action and other exclusive features of the DeZurik valves. Sizes and other specification are included.—DeZurik Corporation

417*R*

Vertical Turbine Pumps—This bulletin, diagrammed in color, discusses water lubricated vertical turbine pumps in capacities of from 15 to 15,000 GPM.—Worthington Corp.

418*R*

Vitrified Clay Pipe—A series of engineering Handbooks on Vitrified Clay Pipe.—National Clay Pipe Mfgr. Inc.

419*R*

Walking Beam Flocculators—A question and answer booklet on Walking Beam Flocculating Equipment.—Stuart Corp.

420*R*

Wash Water Troughs—This new bulletin illustrates and describes fiberglass plastic wash troughs.—F. B. Leopold Co., Inc.

421*R*

Water & Sewage Valves—A 20 page catalog offering complete information on the many types of Crispin air valves for positive air control on water and sewage lines.—Multiplex Mfg. Co.

422*R*

Water & Waste—This bulletin offers 24-pages of illustrations and description covering the major equipment designed and manufactured by the company for water, waste and sewage treatment.—Walker Process Equipment Inc.

423*R*

Water and Waste-Water Treatment—Bulletin 35-D illustrates and describes equipment used for treatment of water, sewage and trade wastes.—Hardinge Company, Incorporated

424*R*

Water Clarification—Hagan Coagulant Aids Nos. 7, 11 and 18, used to improve floc formation in clarifying and soften-

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ing municipal, industrial and oil field water systems, are described in this bulletin.—Hagan Chemical & Controls, Inc.

425*R*

Water Conditioning Plant Package—This bulletin describes the operation of equipment which makes up the package water conditioning plant. This package plant is available in 8 standard sizes ranging from 500 to 3300 gph.—The Permutit Co.

426*R*

Water Leak Locator—This bulletin describes this new listening device for locating water leaks in pipes.—Aqua Survey & Instrument Co.

427*R*

Water Main Cleaning—A reprint on maintaining Pipeline Coefficient "C" after water main cleaning, from the NEWWA Journal—National Water Main Cleaning Co.

428*R*

Water Main Cleaning—Bulletin describes the complete service for the cleaning and restoration of clogged water mains. New techniques developed provide the maximum in efficiency and economy.—National Power Rodding Corp.

429*R*

Water Main Cleaning—This catalog describes equipment for cleaning water mains of all sizes and in all conditions. Offers rodding equipment for hard deposits and short sections with sharp bends or pressure line scrapers, operated by water pressure for longer sections.—Flexible Inc.

430*R*

Water Re-Use—Technical Reprint T-129 discusses the treatment of sewage plant effluent for process and boiler feedwater uses. Dealing with a most important subject of water re-use, this paper indicates some of the considerations and details of this type of process.—Graver Water Conditioning Co.

431*R*

Water Screens—This bulletin fully describes traveling water screens designed for positive removal of floating debris and suspended matter from power station and water treatment plant influent. —The Jeffrey Mfg. Co.

432*R*

Waterstops, Concrete—Catalog sheet presenting specifications drawings of the labyrinth, flextrip, cellular and dumbbell waterstops.—Water Seals, Inc.

433*R*

Waterstops, Plastic—Literature describing diaphragm-type waterstops for expansion and construction joints.—Electrovert, Inc.

434*R*

Waterstop, Plastic—Literature describes a new type of polyvinyl plastic labyrinth waterstop that can be installed in a matter of seconds.—Water Seals, Inc.

435*R*

Water Storage Tanks—This single page offers in handy form the sizes and capacities available in the various water storage tanks offered by the company. Elevated water tanks, pump suction tanks, standpipes and reservoirs are listed.—Graver Tank & Mfg. Co., Inc.

436*R*

Water Treatment—Reference folder serves as a convenient file on the use of activated silica sol as coagulant aid for treating raw, process and waste waters. Advantages are cited and a list of metals protected are included.—Philadelphia Quartz Co.

437*R*

Water Treatment Equipment—A general descriptive brochure indicating the types of water treatment equipment available from the company.—Graver Water Conditioning Co.

438*R*

Water Treatment Equipment—A new booklet (4433) describes modern water treatment equipment and discusses the methods of selection of equipment for various systems. —The Permutit Co.

439*R*

Water Treatment Plant—This fully-illustrated 28-page bulletin covers the "Accelator" treatment plant.—Infilco Incorporated.

440*R*

Well Screens—General information, specifications and typical installations of Johnson Well Screens. Also available are sets of technical bulletins dealing with ground water problems such as corrosion and incrustation.—Edward E. Johnson, Inc.

441*R*

Waterworks Products—This general bulletin describes miscellaneous Clow products, including cutting-in valves, waterworks sleeves, and other cast iron specials.—James B. Clow & Sons, Inc.

442*R*

Well Strainers—A new 48-page, catalog describes the self-cleaning V-shaped slot well strainers, and contains information concerning the recommended procedure for well strainer installation, uses, etc.—Cook Well Strainer Co.

443*R*

Well Water Systems—Bulletin 100 illustrates and discusses pumps, drilling, allied services and equipment available from the company.—Layne & Bowler, Inc.

444*R*

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445*R*

Wrought Iron O.D. Piping—Eight pages highlight wrought iron's durability in large O.D. applications. Included are specific water and sewage service records, recent installations, and an account of the famous Virginia City Pipe line.—A. M. Byers Co.

446*R*

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447*R*

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448*R*

Zeolite Water Softeners—This bulletin describes the zeolite exchange water softening process, includes details of equipment design and basic sizing tables.—Graver Water Conditioning Co.

449*R*

Zeolite Water Softeners—This 20-page bulletin details the troubles caused by using hard water and the many economies effected by curing these troubles. The bulletin also contains equipment specifications, operating characteristics, and data on Permutit ion exchange resins.—The Permutit Co.

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For the Index to the Reference and Data Material, and the Index to Advertisers, See the Rear Section of this Issue.

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- Valves, Hydraulic Cylinder Operated
- Valves, Motor Operated
- Valves, Special, Automatic (Including Remote Control)
- Venturi Tubes
- Water Level Control
- Water Level Recorders

J. C. Fitzgerald Engr. Co.
P.O. Box 289
Coral Gables, Florida

- Sewer Cleaner

Flexible Inc.
3786 Durango Ave.
Los Angeles 34, Calif.

- Cleaning Water Mains
- Pipe Test Plugs
- Pipe Tools (Cutters, Extractors, Threaders, Wrenches, Etc.)
- Sewer Cleaning Equipment and Service
- Water Main Cleaning

Ford Meter Box Co., Inc.
PO Box 376
Wabash, Ind.

- Meter Accessories-Boxes, Housing, Setting
- Meter Couplings, Yokes
- Meter Testing Equipment
- Valve Boxes

Foster Engineering Co.
835 Lehigh Ave.
Union, New Jersey

- Meters, Flow Tube

Foxboro Co.
298 Neposet Ave.
Foxboro, Mass.

- Controllers-Flow, Level Pressure, Temperature,
- Electrical Control Equipment
- Meters, Flow Tube
- Meters, Gas
- Operating Tables (Filter)
- Orifices
- Pitot Tubes
- Rate of Flow Controllers
- Rate of Flow Recorders
- Venturi Tubes
- Water Level Controllers
- Water Level Recorders

Frontier Chemical Co.
Div. of Union Chemical and Materials Corp.
Wichita, Kansas
- Acid Sulfuric and Hydrochloric
- Chlorine, Liquid

G

Gar Wood Industries, Inc.
36253 Michigan Ave.
Wayne, Mich.
- Ditchers
- Trenchers

General Chemical Div.
Allied Chemical Corp.
40 Rector St.
New York 6, N. Y.
- Acid Sulfuric and Hydrochloric
- Activated Alum
- Ammonia, Anhydrous and Aqua
- Dechlorinating Equipment and Chemicals
- Filter Alum
- Insecticides
- Laboratory Apparatus Reagents and Equipment
- Sodium Phosphates (Glassy)
- Sodium Silicate
- Taste and Odor Removal Chemicals
- Weed Killers
- Well Cleaning Chemicals

General Filter Co.
923 2nd Street
Ames, Iowa
- Agitators
- Boiler Feedwater Treatment & Equipment
- Carbonators (Recarbonation)
- Chemical Feeding & Proportioning Equip.
- Clarifiers, Sewage & Water
- Controllers Flow, Level, Pressure, Temperature
- De-Mineralization Equipment (Water)
- Diatomite Filter Septums
- Electrical Control Equipment
- Filter Equipment
- Filter Underdrains, Water
- Flocculating Equipment
- Gas Diffusers
- Indicators, Large Dial Illuminated
- Operating Tables (Filter)
- Orifices
- Rate of Flow Controllers
- Rate of Flow Recorders
- Sludge Collectors
- Tank Linings
- Trickling Filter Equipment
- Water Softening Equipment
- Water Treatment for Scale & Corrosion
- Zeolite & Zeolite Softeners

General Services Co.
P.O. Box 612
Corvallis, Oregon
- Pumping Rate Control

Glenfield & Kennedy Inc.
706 North Ave.
New Rochelle, New York
- Filter Equipment
- Strainers-Suction

The Globe Co.-Grip Strut Div.
4026 S. Princeton Ave.
Chicago 9, Ill.
- Gratings, Floorways, Treads

Golden-Anderson Valve Spec. Co.
1232 Ridge Ave.
Pittsburgh 33, Pa.
- Valves, Altitude
- Valves, Check
- Valves, Cone
- Valves, Float
- Valves, Motor Operated
- Valves, Pressure Reducing
- Valves, Relief
- Valves, Rubber, Plastic, Glass, Lead
- Valves, Special automatic including Remote Control

Graver Tank & Mfg. Co.
4809 Tod Ave.
E. Chicago, Ind.
- Bins
- Breechings
- Elevated Water Tanks
- Gas Holders
- Pressure Tanks
- Pump Suction Tanks
- Reservoirs
- Stacks
- Standpipes
- Storage Tanks

Graver Water Conditioning Co.
216 W. 14th Street
New York 11, N. Y.
- Activated Carbon
- Aeration Apparatus
- Agitators
- Anthrafilt
- Bins, Storage
- Boiler Feedwater Treatment and Equipment
- Carbonators (Recarbonating)
- Chemical Feeding and Proportioning Equipment
- Clarifiers, Sewage and Water
- Dechlorinating Equipment and Chemicals
- Demineralization Equipment (Water)
- Diatomite Filter Septums
- Feed Water Heaters
- Filters
- Filter Equipment
- Filter Media
- Filter Underdrains, Water
- Flocculating Equipment
- Grit Chamber Equipment and Grit Washers
- Mixers and Mixing Equipment
- Operating Tables
- Sludge Collectors
- Thickeners (Sludge)
- Water Softening Equipment
- Zeolite
- Zeolite Softeners

Grinnell Co., Inc.
Providence, R. I.
- Brass Goods
- Fittings, Tees, Ells
- Jointing Compounds, Materials
- Joints, Mechanical, Flexible
- Nozzles, Spray, Water and Sewage
- Orifices
- Pipe-Fittings, Lined
- Sewer Pipe Joints & Jointing Compounds
- Valves, Check
- Valves, Chlorine
- Valves, Diaphragm
- Valves, Hydraulic (Cylinder operated)
- Valves, Foot
- Valves, Special Automatic (Including Remote Control)

H

Hagan Chemicals & Controls, Inc.
Hagan Building
Pittsburgh 30, Pennsylvania
- Flow (measuring, recording, indicating and controlling)
- Pressure (measuring, recording, indicating and controlling)
- Temperature (measuring, recording, indicating and controlling)
- Level (measuring, recording, indicating and controlling)
- pH (measuring, recording, indicating and controlling)
- Blending controlling
- Chemical feed controlling
- Loss of head measuring and recording equipment
- Filter rate of flow measuring and recording
- Electric measurement transmitting
- Pneumatic measurement transmitting
- Flow integrators, local and remote
- Primary measuring elements
- Valve positioners
- Water conditioners

Hamilton Kent Mfg. Co.
427 W. Grant St.
Kent, Ohio
- Coatings, Acid and Alkali-Proof
- Couplings, Flexible
- Joints, Mechanical Flexible
- Rubber Packing Gaskets

Hardinge Co., Inc.
240 Arch Street
York, Pa.
- Agitators
- Castings, Iron, Steel, Alloy Steel
- Clarifiers, Sewage and Water
- Drying Systems (Sludge)
- Filter Equipment
- Flocculating Equipment
- Sludge Collectors
- Thickeners (Sludge)

Healy-Ruff Company
783 Hampden Ave.
St. Paul 4, Minn.
- Alternators, Electric
- Controllers Flow, Level, Pressure, Temperature
- Electrical Control Equipment
- Gages (Liquid Level, Pressure Recording)
- Indicators, Large Dial Illuminated
- Pumping Controls
- Water Level Control

Hersey Mfg. Company
P.O. Box 31
Dedham, Mass.
- Meter Repair Parts
- Meters (Turbine Type)
- Meter Testing Equipment
- Meters, Water (Consumer)
- Testers (Water Meter)
- Valves, Check
- Valves, Water Meter Special

Hollaender Mfg. Co.
3841 Spring Grove Ave.
Cincinnati, Ohio
- Gratings, Floorways, Treads, Railings

Homelite Corp.
Div. of Textron Inc.
67 Riverdale Ave.
Port Chester, N. Y.
- Blowers Air, Gas
- Engine-Generator Unit
- Generators (Electric)
- Pumps, Centrifugal
- Pumps, Diaphragm
- Pumps, Portable
- Pumps, Self-Priming

Homestead Valve & Mfg. Co.
Box 348
Cerapolis, Pa.
- Cocks (Curb Meter, Corp. etc)
- Valves, Cone
- Valves, Four Way
- Valves, Hydraulic Cylinder Operated
- Valves, Lubricated Plug
- Valves, Motor Operated
- Valves, Mud and Plug

Hooker Chemical Co.
Niagara Falls, New York
- Chlorine, Liquid

Hydraulic Development Co.
West Bedford, Mass.
- Chains (Elevating, Conveying & Power Transmission)
- Jointing Compound and Materials
- Laboratory Apparatus Reagents and Equipment
- Pipe Joint Tools
- Sewer Pipe Joints (and Jointing Compounds)

I

Industrial Chem. Sales Div.
West Virginia Pulp & Paper Co.
230 Park Ave.
New York, New York
- Activated Carbon Deodorizing

Infilco Inc.
PO Box 5033
Tucson, Arizona
- Acid Feeders
- Aerators
- Activated Sludge Plants
- Automatic Controls
- Boiler Feed Treatment Plants
- C.-A.-P. SYSTEM® Instruments
- Chemical Feeders and Proportioners
- Clairifiers
- Coagulant Feeders
- Coagulators
- Clarification Plants
- Depth Gauges
- Diatomite Filters
- Digester Mixing & Heating Equipment
- Diffusers
- Filter Operating Tables and Consoles
- Filter Plant Equipment
- Filter Underdrains
- Floating Covers
- Flotation Equipment

R-416A

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Grease and Grit Removal Systems
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Liquid Level Controls and Gauges
Loss of Head Gauges
Manometers
Mixing Equipment
Mobile Water Purification Plants
Pressure Filters
Rate of Flow Controllers and Gauges
Rotagrator Screen and Comminutor
Rotary Distributors
Sampling Tables
Sand Filters
Sewage Treatment Plants
Venturi Tubes and Meters
Wagner Underdrains
Wash Water Controllers
Zeolite Water Softeners

Ingalls Iron Works
Birmingham, Ala.
Steel, Fabricating
Tanks & Standpipes

International Minerals, Inc.
20 N. Wacker Drive
Chicago, Ill.
Acid Sulfuric and Hydrochloric
Chlorine, Liquid
Fluoridation Chemicals

Iowa Valve Co.
201 W. Talman Ave.
Chicago, Ill.
Hydrants
Inserting Sleeves Valve
Meter Accessories, Boxes, Housing, Setting
Valve Boxes
Valves, Motor Operated
Valves, Mud & Plug

J

The Jeffrey Mfg. Co.
947 N. 4th St.
Columbus 16, Ohio
Aeration Apparatus
Agitators
Ash and Coal Handling Machinery
Bins, Storage
Castings, Iron, Steel, Alloy Steel, Etc.
Chains (Elevating, Conveying & Power Transmission)
Chemical, Conveying Equipment
Chemical Feeding & Proportioning Equipment
Clarifiers, Sewage & Water
Conveyors & Conveying Equipment
Couplings, Flexible
Digester Equipment (Sludge)
Flocculating Equipment
Grit Chamber Equipment & Grit Washers
Mixers & Mixing Equipment
Screens, Intake
Screens, Sewage
Screens, Vibrating
Sludge Collectors
Sludge Disintegrators
Sludge Samplers
Thickeners (Sludge)
Valves, Check
Valves, Gate

Johns-Manville Corp.
22 E. 40th St.
New York 16, N. Y.
Bituminous Coatings and Linings
Cements, Acid Proof and Alkali
Cements, Refractory
Cements, Sewer Pipe
Coatings, Acid and Alkali-Proof
Couplings, and Connections Pipe
Couplings, Flexible
Filter Aids
Forms and Gaskets for Pipe Joints
Gratings, Flooring, Treads, Railings
Insulation
Jointing, Compound and Materials
Joints, Expansion-Pipe
Packing (Pumps and Valves)
Pipe and Tank Coatings
Pipe, Asbestos-Cement
Pipe Joint Packing
Pipe, Sewer
Pipe Wrapping
Refractories
Roof Coatings
Rubber Packing Gaskets
Sewer Pipe Joints (and Jointing Compounds)

Edward E. Johnson, Inc.
315 N. Pierce
St. Paul, Minn.
Diatomite Filter Septums
Filter Media
Screens, Water Well

John Wiley Jones Co.
Caledonia, N. Y.
Ammonia, Anhydrous & Aqua
Calcium Hypochlorite
Chlorine, Liquid
Taste & Odor Removal Chemicals

K

Keasbey & Mattison Co.
Ambler, Pa.
Jointing Compound Materials
Pipe, Asbestos, Cement
Pipe, Joint Packing

Kerrigan Iron Works, Inc.
274 Madison Ave.
New York, N. Y.
Gratings, Floorings
Treads—Steel, Stainless & Aluminum

Klett Mfg. Co.
179 E. 87th St.
New York 28, N. Y.
Gates, Sluice
Laboratory Apparatus, Reagents, & Equipment
Turbidimeters

Komline-Sanderson Eng. Corp.
Peapack, New Jersey
Drying Systems (Sludge)
Feeders, Chemical
Filters, Vacuum
Meider Collectors
Pumps, Sludge
Sewage Ejectors, Pneumatic

Kuhn Brothers Co.
1800 McCall St.
Dayton, Ohio
Fittings, Ductile Iron

L

Layne & Bowler, Inc.
1993 Chelsea Ave.
Memphis, Tenn.
Contractors
De-Mineralization Equip.
Drilling & Boring Equip.
Filter Equipment
Pumps, Deep Well
Pumps, Sewage & Drainage
Pumps, Turbine
Water Softening Equipment
Well Cleaning Chemicals
Wells, Complete

Leupold & Stevens Instruments Inc.
4445 N. E. Glisan
Portland 13, Oregon
Controllers, Flow, Level, Pressure, Temperature
Flow Meters
Gages
Indicators, Large Dial Illuminated
Rate of Flow Recorders
Water Level Controllers
Water Level Recorders

F. B. Leopold Co., Inc.
227 S. Division St.
Zelienople, Pa.
Chemical Feeders
Contractors
Filter Equipment
Filter Underdrains
Flocculating Equipment
Butterfly Valves
Filter Operating Tables
Samplers
Sampling Tables
Four-Way Valves
Fiberglass Reinforced Plastic Wash Water Troughs
Hydra-Pneumatic Control Systems

Link Belt Co.
Prudential Plaza
Chicago 1, Ill.
Air Diffusor Units
Agitators
Ash Handling Equipment
Bar Screens
Bearings, Ball, Babbitted, Roller
Belt Conveyors
Bins, Storage
Bio-Filtration Equipment
Bucket Elevators
Car Spotters
Castings
Chains and Sprockets (Elevating, Conveying and Power Transmission
Chemical Feeding and Proportioning Equipment
Chemical Conveyor Equipment
Circuline Collectors
Clairifiers, Sewage & Water
Collectors, Sludge and Dirt
Conveyors and Conveying Equipment
Couplings, Flexible, Rigid and Fluid
Dryers and Coolers, Sludge
Drum Screens
Feeders, Vane
Flash Mixers
Flocculation Equipment
Gearmotors
Grit Chambers, Collectors and Washers
Industrial Waste Recovery Equipment
Liquid Vibrating Screens
Mixers and Mixing Equipment
Nozzles, Spray
Power Transmission Equipment
Revolving Screens
Rotary Screens
Sewage Treatment Equipment
Screens—Bar, Drum, Revolving, Trash, Sewage, Vibrating, Water In-Take
Screw Conveyors
Scum Breakers
Sludge Collectors
Speed Reducers
Straightline Bar Screens and Collectors
Thickeners (Sludge)
Trash Screens
Tritor Screens
Variable Speed Drives
Valves, Gate for Bulk Materials
Vibrating Screens
Water Intake Screens

Lock Joint Pipe Co.
150 Rutledge Ave.
East Orange, N. J.
Concrete Pipe
Pipe, Concrete Pressure

Ludlow Valve Mfg. Co.
Ft. of Adams St.
Troy, N. Y.
Gates, Shear
Gates, Sluice
Gate Valve Operator
Hydrants
Inserting Sleeves, Valve
Sleeves, Tapping
Valve Boxes
Valves, Air Release & Vacuum Breakinn
Valves, Butterfly
Valves, Check
Valves, Flap
Valves, Float
Valves, Foot
Valves, Four Way
Valves, Mud and Plug

M

M & H Valve & Fittings Co.
Anniston, Alabama
Hydrants
Inserting Sleeves Valve
Sleeves, Pipe Repair
Valves, Gate
Valves, Mechanical Joint
Valves, Motor Operated
Valves, Mud & Plug

M. C. G. Company
1851 Bedford Street
Columbus, Ohio
Filter Underdrains Water

W. R. Meadows, Inc.
16 Kimball Street
Elgin, Ill.
Waterstops

Millipore Filter Corp.
36 Pleasant St.
Watertown 72, Mass.
Filter Equipment
Laboratory Apparatus, Reagents & Equipment

Merrick Scale Co.
184 Autumn St.
Passaic, N. J.

Scales, Sludge

Minneapolis-Honeywell Regulator Co.
Wayne & Windrin Aves.
Philadelphia 44, Pa.
- Boiler Feedwater Treatment and Equipment
- Chemical Feeding and Proportioning Equipment
- Combustion Indicators and Recorders
- Controllers Flow, Level, Pressure, Temperature
- Electrical Control Equipment
- Filter Equipment
- Flow Meters
- Gages (Liquid Level, Pressure Recording)
- Gas Indicator and Detectors
- Manometers
- Meteorological Instruments
- Meter, Flow Tube
- Meters, Gas
- Meter Testing Equipment
- Meters, Venturi
- Operating Tables (Filter)
- Orifices
- Pumping Controls
- Rate of Flow Controllers
- Rate of Flow Recorders
- Regulators, Pressure (Water and Gas)
- Telemetering Equipment
- Valves, Chlorine
- Valves, Diaphragm
- Valves, Motor Operated
- Water Level Controllers
- Water Level Recorders

Modern Swimming Pool, Inc.
1 Holland Ave.
White Plains, N. Y.
- Chemical Feeding & Proportioning Equipment
- Chlorinators
- Chlorine, Liquid
- Coagulating Aids
- Drains, Gutter, Floor
- Filter Aids
- Water Softening Equipment

Morse Boulger Destructor Co.
80 Fifth Ave.
New York, N. Y.
- Conveyors & Conveying Equipment
- Drying Systems (Sludge)
- Gates, Sluice
- Incinerators (Sludge & Garbage)
- Pumps, Diaphragm

J. W. Mortell Co.
580 Burch St.
Kankakee, Illinois
- Coatings, Acid & Alkali Proof
- Corrosion Suppression
- Pipe & Tank Coatings
- Tank Maintenance & Repair
- Waterproofing, Paints, Compounds & Materials

Morton Salt Co.
110 N. Wacker Dr.
Chicago 6, Ill.
- Brinemakers
- Salt

Mueller Co.
512 Cerro Gordo St.
Decatur 8, Ill.
- Calking Tools
- Clamps & Sleeves, Pipe Clamps, Pipe Repair
- Corporation Stops
- Corrosion Suppression
- Curb Boxes
- Curb Stops
- Drilling Machines
- Fittings, Tees, Ells
- Floor Stands
- Gates, Shear
- Gates, Sluice
- Gate Valve Operator
- Goose Necks
- Hydrants (Fire)
- Indicator Posts
- Inserting Valves
- Laboratory Apparatus
- Lubricants, Valve
- Meter Accessories
- Meter Couplings, Yokes
- Pipe, Copper
- Pipe Joint Tools
- Pipe Tapping Machines
- Regulators, Pressure
- Saddles, Pipe
- Sleeves, Pipe Repair
- Sleeves, Tapping
- Strainers
- Valve Boxes
- Valves, Check
- Valves, Flap
- Valves, Gate
- Valve Inserting Equipment
- Valves, Mud & Plug
- Valves, Pressure Reducing
- Valves, Relief
- Valves, Tapping

Multiplex Mfg. Co.
Berwick, Pa.
- Joints, Slip
- Valves, Air Relief, Vacuum Breaking
- Valves, Sewer
- Valves, Surge & Water Hammer

N

Natco Corp.
327 5th Ave.
Pittsburgh 22, Pa.
- Bins, Storage
- Filter Underdrains, Sewage
- Pipe Sewer
- Trickling Filter Equipment

National Clay Pipe Mfgrs. Inc.
1820 N. St. N. W.
Washington 6, D. C.
- Filter Underdrains, Water
- Pipe, Sewer

National Power Rodding Corp.
1000 South Western Ave.
Chicago 12, Ill.
- Cleaning Water Mains
- Cleaning Sewer Mains

National Water Main Cleaning Co.
50 Church St.
New York 7, New York
- Cleaning Water Mains
- Pipe, Cement Lining of

Neptune Meter Co.
19 W. 50th St.
New York 20, N. Y.
- Meter Couplings
- Meter Repair Parts
- Meters, Gas
- Meters (Turbine Type)
- Meter Testing Equipment
- Meters, Water
- Trap, Sediment

Newport News Shipbuilding & Dry Dock Co.
Newport News, Va.
- Rack Rakes
- Gates, Sluice

Nichols Eng. & Research Corp.
70 Pine Street
New York 5, N. Y.
- Driers, Sludge
- Incinerators

Norse Electric Co.
55 Water St.
New York, N. Y.
- Filters, Diesel Oil
- Filters, Engine Oil

O

Olin Mathieson Chemical Corp.
Indus. Chem. Div.
Mathieson Bldg.
Baltimore 3, Maryland
- Acid Sulfuric and Hydrochloric
- Ammonia, Anhydrous and Aqua
- Calcium Hypochlorite
- Chlorine, Liquid
- Deodorizing
- Soda Ash
- Sodium Hypochlorite
- Water Treatment for Scale and Corrosion
- Well Cleaning Chemicals

The Oliver Corp.
400 W. Madison Street
Chicago 6, Ill.
- Earth Moving Equipment
- Trenching Equipment

Omega Machine Co.
Div. of B-I-F Industries Inc.
350 Harris Ave.
Providence, R. I.
- Activated Silica Generators
- Ammoniators
- Chemical Feeding & Proportioning Equipment
- Conveyors & Conveying Equipment
- Dechlorinating Equipment & Chemicals
- Electrical Control Equipment
- Ferric Chloride
- Water Treatment for Scale & Corrosion

P

Pacific Flush Tank Co.
4141 Ravenswood Ave.
Chicago 13, Ill.
- Aeration Apparatus
- Arresters, Flame
- Diffusers-Plates, Tubes & Fittings
- Digester Equipment
- Distributors (Sewage Filter)
- Gages (Liquid Level, Pressure Recording)
- Gas Holders
- Heaters, Digesters
- Manometers
- Siphons
- Trickling Filter Equipment
- Valves, Relief

Waste Gas Burners

Peerless Pump Div.
Food Mchy. & Chem. Corp.
301 W. Ave. 26
Los Angeles 31, Calif.
- Pumps, Acid Handling
- Pumps, Centrifugal
- Pumps, Deep Well
- Pumps, Portable
- Pumps, Self-Priming
- Pumps, Sewage & Drainage
- Pumps, Sludge
- Pumps, Sump (and Cellar Drainer)
- Pumps, Turbine

Pennsalt Chemicals Corp.
3 Penn Center Plaza
Philadelphia 2, Pa.
- Acid Sulfuric and Hydrochloric
- Activated Alum
- Ammonia, Anhydrous and Aqua
- Calcium Hypochlorite
- Cements, Acid Proof and Alkali
- Chlorine, Liquid
- Coagulating Aids
- Coatings, Acid and Alkali Proof
- Ferric Chloride
- Filter Alum
- Insecticides
- Paint (Acid Resisting)
- Sodium Hypochlorite
- Sodium Phosphates (Glassy)

Pennsalt Chem. Corp. Western Div. of Pennsalt Chemicals Corp.
2901 Taylor Way
Tacoma, Washington
- Acid Sulfuric and Hydrochloric
- Ammonia, Anhydrous and Aqua
- Calcium Hypochlorite
- Chlorine, Liquid
- Ferric Chloride
- Insecticides
- Sodium Hypochlorite
- Sodium Phosphates (Glassy)

Permutit Company
Div. Pfaudler Permutit Inc.
50 W. 44th St.
New York 36, N. Y.
- Aerators
- Activated Carbon
- Automatic Control Tables and Cubicles
- Boiler Feedwater Equipment
- Chemical Feeders
- Carbon Dioxide Indicators and Recorders
- Cold Lime and Lime-Soda Process Water Softeners
- Deaerators
- Demineralizing Equipment
- Filter, Gravity and Pressure
- Hot Process Water Softeners
- Ion Exchange Resins
- Iron and Manganese Removal Equipment
- Precipitators
- Valves, Multiport—Automatic or Manual
- Zeolites and Zeolite Water Softeners

Phelps Dodge Refining Corp.
300 Park Ave.
New York, N. Y.
- Taste and Odor Removal Chemicals

PhiladelphiaQuartz Co.
Public Ledger Bldg.
Independence Square
Philadelphia, Pa.
- Coagulating Aids
- Bituminous Coating & Linings

Phipps & Bird Co.
6th & Byrd Sts.
Richmond 5, Va.
- Boiler Feedwater Treatment & Equipment
- Buffer Solutions & Tablets
- Comparators Color
- De-Mineralization Equipment (Water)
- Laboratory Apparatus Reagents & Equipment
- pH Test Equipment
- Photoelectric Colorimeters
- Pumps, Vacuum
- Residual Chlorine Test Apparatus
- Samplers & Sampling Tables
- Sewage Samplers
- Sludge Samplers
- Stirrers
- Turbidimeters

Pittsburgh-Des Moines Steel Co.
3456 Neville Island
Pittsburgh, Pa.
- Bins, Storage
- Breechings Steel
- Floating Covers
- Gas Holders

Jos. G. Pollard Co.
New Hyde Park
Long Island, N. Y.
- Jointing Compound & Materials
- Pipe Tools
- Valve Box Locators

Portland Cement Assn.
Dearborn & Grand Ave.
Chicago 10, Ill.
- Concrete Pipe (Water & Sewage)

Henry Pratt Co.
2222 S. Halsted St.
Chicago 8, Ill.
- Valves, Butterfly
- Valves, Hydraulic Cylinder Operated
- Valves, Mechanical Joint

Precision Chemical Pump Corp.
1396 Main St.
Waltham 54, Mass.
- Pumps, Chemicals

Preload Corp.
211 E. 37th St.
New York, N. Y.
- Bins, Storage
- Contractors, Water & Sewage

Prestite-Keystone Eng. Products Co.
3738 Chouteau Ave.
St. Louis 10, Mo.
- Bituminous Coatings & Linings
- Cements, Sewer Pipe
- Forms & Gaskets for Pipe Joints
- Jointing Compound & Materials
- Roof Coatings
- Sewer Pipe Joints

Pressure Concrete Co.
1555 Helton St.
Florence, Alabama
- Gunite Contracting

J. R. Prewitt & Sons, Inc.
Pleasant Hill, Mo.
- Drills, Auger
- Diggers

Price Bros. Co.
1150 E. Monument Ave.
Dayton, Ohio
- Pipe, Concrete, Pressure
- Pipe, Culvert
- Pipe, Sewer
- Saddles, Pipe
- Siphons (Sewage Dosing)

Proportioneers, Inc.
Div. of B-I-F Industries Inc.
350 Harris Ave.
Providence, R. I.
- Boiler Feedwater Treatment & Equipment
- Calcium Hypochlorite
- Chemical Feeding & Proportioning Equipment
- Chlorinators
- Dechlorinating Equipment & Chemicals
- Diatomite Filter Septums
- Ferric Chloride
- Filter Equipment
- Filter Media
- Filters, Vacuum
- Fluoridation Equipment
- Laboratory Apparatus, Reagents & Equipment
- Pumps, Diaphragm
- Rust Prevention
- Sewage Samplers
- Water Softening Equipment
- Water Treatment for Scale & Corrosion

R

Rensselaer Valve Co.
Troy, New York
- Gates, Sluice
- Hydrants (Fire)
- Sleeves, Tapping (Valve)
- Valves, Flap
- Valves, Foot
- Valves, Gate
- Valves, Hydraulic Cylinder Operated
- Valves, Mechanical Joint
- Valves, Motor Operated

Roberts Filter Mfg. Co.
640 Columbia Ave.
Darby, Pa.
- Boiler Feedwater Treatment & Equipment
- Filter Equipment
- Filter Underdrains Water
- Flocculating Equipment
- Operating Tables (Filter)
- Sludge Valves (Telescopic)
- Valves, Mud and Plug
- Water Softening Equipment
- Zeolite & Zeolite Softeners

Robinson Pipe Cleaning Co.
Box 300
Canonsburg, Pa.
- Cleaning, Water Mains
- Cleaning, Sewers

Rockwell Mfg. Co.
400 N. Lexington Ave.
Pittsburgh, Pa.
- Lubricants, Valve
- Meters, Water
- Regulators, Pressure
- Valves, Four Way
- Valves, Motor Operated
- Valves, Mud & Plug
- Valves, Hydraulic Cylinder Operated
- Valves, Lubricated Plug
- Valves, Mechanical Joint

W. S. Rockwell Co.
2763 Eliot Street
Fairfield, Conn.
- Rubber Lined Pipes & Valves
- Valves, Check
- Valves, Float
- Valves, Gate
- Valves, Hydraulic Cylinder Operated
- Valves, Motor Operated

Royer Foundry & Mach. Co.
158 Pringle Street
Kingston, Pa.
- Sludge Disintegrators

S

Safety Gas Main Stopper Co.
523 Atlantic Ave.
Brooklyn, N. Y.
- Stoppers, Water Main

Schramm, Inc.
West Chester, Pa.
- Compressors, Air
- Concrete Breakers
- Drilling & Boring Equipment

Shahmoon Industries, Inc.
Warren Foundry & Pipe Div.
55 Liberty St.
New York 5, N. Y.
- Pipe, Cast Iron

Simplex Valve & Meter Co.
7 E. Orange Street
Lancaster, Pa.
- Controllers Flow, Level, Pressure, Temperature
- Filter Equipment
- Gages (Liquid Level, Pressure Recording)
- Indicators, Large Dial Illuminated
- Manometers
- Meters, Electric
- Operating Tables (Filter)
- Orifices
- Rate of Flow Controllers
- Rate of Flow Recorders
- Sand Expansion Indicators
- Valves, Air Release & Vacuum Breaking
- Venturi Tubes
- Water Leak, Locating Instruments
- Water Level Controllers
- Water Level Recorders

Smith-Blair, Inc.
535 Railroad Ave.
So. San Francisco, Calif.
- Adapters, Flanged Coupling, Mechanical Joint
- Caps, Pipe End
- Clamps, Pipe Repair
- Couplings, Mechanical Joint Straight & Reducing
- Fabrications, Pipelines
- Joints, Expansion
- Rings, Water Lock
- Saddles, Tapping, Repair
- Sleeves, Tapping
- Tees, Cast

A. P. Smith Mfg. Co.
East Orange, N. J.
- Pipe Test Plugs
- Sleeves, Tapping (Valve)
- Valve Boxes
- Valve Inserting Machines
- Valves, Check
- Valves, Gate
- Valves, Hydraulic Cylinder Operated
- Valves, Mechanical Joint
- Valves, Motor Operated

S. Morgan Smith Co.
York, Pa.
- Valves, Altitude
- Valves, Butterfly
- Valves, Check
- Valves, Cone
- Valves, Diaphragm
- Valves Float
- Valves, Hydraulic Cylinder operated
- Water Level Controllers

Smith & Loveless, Inc.
96th St. & Old 50 Highway
Lenexa, Kansas
- Chlorinators
- Distributors, Rotary
- Filters, Swimming Pool
- Recarbonators
- Sewage Ejector Stations
- Sewage Pumping Stations
- Sewage Pumps
- Sewage Treatment Plants
- Water Mixers, Flocculators
- Water Pumping Stations

Sparling Meter Company
225 N. Temple City Blvd.
El Monte, Calif.
- Meters, Water Compound

Speelmon Elevated Tank Service
822 N. Court Street
Rockford, Ill.
- Tank Linings
- Tank Maintenance & Repair

Spring Load Mfg. Co.
3610 First Ave. South
Seattle, Wash.
- Pipe Cutting Machines
- Pipe Tools (Asbestos, Cement)

J. S. Staedtler, Inc.
25 Dicarolis Court
Hackensack, N. J.
- Drafting Pencils
- Drafting Leads
- Drafting Lead Holders

Standard Dry Wall Products, Inc.
Box X
New Eagle, Pa.
- Concrete Hardener
- Pipe, Cement Lining of
- Waterproofing Paints, Compounds, and Materials

Standard Steel Corp.
5067 S. Boyle Ave.
Los Angeles 58, Calif.
- Drying Systems, Sludge

Stuart Corp.
516 N. Charles St.
Baltimore, Md.
- Activated Carbon
- Anthrafilt
- Ash & Coal Handling Machinery
- Conveyors & Conveying Equipment
- Filter Equipment
- Filter Media
- Filter Underdrains, Water
- Flocculating Equipment

Gates, Sluice
Grit Chamber Equipment & Grit Washers
Mixers & Mixing Equipment
Water Softening Equipment

Synchro Start Products, Inc.
8151 N. Ridgeway
Skokie, Ill.
Electrical Control Equipment
Engine Controls

T

W. A. Taylor & Co.
7308 York Rd.
Baltimore 4, Maryland
Comparators Color
Laboratory Apparatus, Reagents & Equipment
pH Test Equipment
Photoelectric Colorimeters

Tennessee Corp.
619 Grant Bldg.
Atlanta, Ga.
Acid Sulfuric & Hydrochloric
Copper Sulfate
Dechlorinating Equipment & Chemicals
Ferric Sulphate
Fluoridation Chemicals
Thickeners (Sludge)

U

U. S. Electrical Motors, Inc.
200 E. Slauson Ave.
Los Angeles 54, Calif.
Gears, Speed Reducing
Motors, Electric
Speed Reducers, Transmission
Variable Speed Transmissions

U. S. Pipe & Foundry Co.
3300 First Ave. N.
Birmingham, Ala.
Cement Lined Pipe and Fittings
Fittings, Pipe
Pipe, Centrifugal Cast Iron
Pipe, Tyton Joint®
Pipe, Mechanical Joint
Pipe, Bell-and-Spigot
Pipe, Flanged
Pipe, Flexible Joint

U. S. Rubber Co.
1230 Avenue of Americas
New York 20, N. Y.
Acid, Sulphuric & Hydrochloric
Chemical, Conveying Equipment
Clamps & Sleeves, Pipe
Coatings, Acid & Alkali-Proof
Couplings, Flexible
Filter Aids
Forms & Gaskets for Pipe Joints
Hose, Air, Steam, Water, Suction
Insecticides
Joints, Expansion Pipe
Lubricants, Valve
Paint (Acid Resisting)
Pipe & Fittings Lined
Pipe & Tank Coatings
Pipe Joints (Mechanical)
Pipe, Plastic
Roof Coatings
Rubber Lined Pipes & Valves
Tank Linings
Tanks, Rubber Lined
Valves, (Rubber, plastic, glass or lead)
Waterproofing Paint, Compounds & Materials
Weed Killers
Well Cleaning Chemicals

V

Vulcan Materials Co.
2019 Sixth Ave. N.
Birmingham, Ala.
Aggregates

W

W-K-M Division of
ACF Industries, Inc.
PO Box 2117
Houston 1, Texas
Valves, Check
Valves, Lubricated plug
Valves, Ball
Valves, Motor Operated
Valves, Special Automatic

Walker Process Equipment Inc.
840 N. Russell Ave.
Aurora, Ill.
Aeration Apparatus
Anthrafilt
Carbonators
Clarifiers, Sewage & Water
Conveyors & Conveying Equipment
Diffusers, Plates, Tubes & Fittings
Distributors, Sewage
Filter Equipment
Filter Underdrains, Sewage
Filter Underdrains, Water Floating Covers
Flocculating Equipment
Gas Diffusers
Gas Holders
Grinders, Garbage & Screenings
Grit Chamber Equipment and Grit Washers
Heaters Digester
Operating Tables (Filter)
Porous Tubes and Plates
Samplers & Sampling Tables
Screens, Sewage
Siphons, Sewage
Sludge Collectors
Sludge Samplers
Trickling Filter Equipment
Valves, Sludge
Valves, Special Automatic including Remote Control
Water Softening Equipment

Wallace & Tiernan Inc.
25 Main St.
Belleville, N. J.
Ammoniators
Activated Silica Equipment
Boiler Feedwater Treatment and Equipment
Chlorinators
Chemical Control Equipment
Chemical Feeding and Proportioning Equipment
Chlorine Control Equipment
Comparators
Dechlorinating Equipment & Chemicals
Gages (Liquid Level, Pressure, Recording)
Gas Indicators & Detectors (Chlorine)
Hypochlorinators
Hydrogen-Ion Equipment
Manometers
pH Test Equipment
Proportioning Equipment
Pumps, Diaphragm
Pumps, Acid Handling
Regulators, Pressure (water & gas)
Residual Chlorine Controllers
Residual Chlorine Test Apparatus
Valves, Chlorine
Water Level Recorders
Water Treatment for Scale & Corrosion

Washington Aluminum Co.
Knecht Ave. & Penn R. R.
Baltimore, Maryland
Gates, Shear
Gratings, Flooring Treads, Railings

Water Seals, Inc.
9 S. Clinton St.
Chicago 6, Ill.
Waterstops

Waukesha Motor Co.
Waukesha, Wisc.
Engines, Gas, Gasoline, LP Gas, Sewage Gas

Weinman Pump Mfg. Co.
286 Spruce Street
Columbus, Ohio
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Sewage & Drainage
Pumps, Sump (& cellar drainer)

WEMCO Torque-Flow Pump Div.
Western Machinery Company
650 Fifth Street
San Francisco 7, California
Agitators
Conditioners
Mixers
Pumps, Sewage Handling
Thickeners

Westinghouse Electric Corp.
Gateway Center, 401 Liberty Ave.
Pittsburgh 30, Pa.
Electrical Control Equipment
Fans Exhaust & Ventilating
Furnaces (Melting, Pouring, Ladles, Pots, etc.)
Gears, Speed Reducing
Generators (Electric)
Meters, Electric
Motors, Electric
Penstocks
Pipe, Plastic
Switchboard & Switch Gear
Transformers, Electric
Turbines, Steam
Valves, Butterfly
Valves, Gate
Valves, Motor Operated

Wheeler Manufacturing Corp.
508 W. 48th St.
Ashtabula, Ohio
Pipe Cutters

White Motor Co.
White Diesel Engine Div.
1401 Sheridan
Springfield, Ohio
Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines, Gas & Gasoline
Engines, Sludge, Gas

John Wiley & Sons, Inc.
440 4th Ave.
New York 16, N. Y.
Books, Technical

R. D. Wood Co.
Public Ledger Bldg.
Philadelphia 5, Penna.
Fittings, Tees, Ells, Etc.
Hydrants (Fire)
Pipe, Cast Iron
Pipe, Cement Lined
Pipe, Culvert
Pipe Joints (Mechanical)
Valve Boxes
Valves, Gate
Valves, Mechanical Joint

Woodward Iron Co.
Woodward, Alabama
Pipe, Cast Iron

Worthington Corp.
Harrison & Worthington Aves.
Harrison, N. J.
Agitators
Comminuting Devices
Compressors, Air
Concrete Breakers
Concrete Mixer
Condensers (Steam)
Drilling & Boring Equipment
Drives, V-Belt
Ejectors, Pneumatic or Steam
Engine-Generator Unit
Engines, Diesel
Engines, Dual Fuel
Engines (Gas & Gasoline)
Engines, Sludge, Gas
Gears, Speed Reducing
Generators (Electric)
Mixers & Mixing Equipment
Motors, Electric
Nozzles, Spray (Water & Sewage)
Orifices
Pumps, Acid-Handling
Pumps, Centrifugal
Pumps, Deep Well
Pumps, Hydraulic (Pressure Boosting)
Pumps, Portable
Pumps, Self-Priming
Pumps, Sewage & Drainage
Pumps, Sludge
Pumps, Sump (And Cellar Drainer)
Pumps, Turbine
Pumps, Vacuum
Switchboard & Switch Gear
Tools, Pneumatic
Turbines, Steam
Valves, Butterfly
Valves, Gate
Variable Speed Transmissions

Worthington Gamon Meter Div.
Worthington Corp.
296 South Street
Newark 5, N. J.
Meters, Water (Consumer)

Y

Yeomans Bros. Co.
1999 N. Ruby St.
Melrose Park, Ill.
Aeration Apparatus
Clarifiers, Sewage & Water
Compressors, Air
Digester Equipment
Distributors, Sewage Filter
Ejectors, Pneumatic or Steam
Nozzles, Spray, Water & Sewage
Pumps, Acid Handling
Pumps, Centrifugal
Pumps, Sludge
Pumps, Sewage & Drainage
Pumps, Vacuum
Pumps, Sump and Cellar Drainer
Trickling Filter Equipment

Z

Zimmer & Francescon
Moline, Illinois
Pumping Stations, Sewage

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